THE SIDEREAL MESSENGER,

CONDUCTED BY WM. W. PAYNE.

DIRECTOR OF CARLETON COLLEGE OBSERVATORY, NORTHFIELD, MINN.

VOL. 10, No. 1. JANUARY, 1891. WHOLE No. 91

THE PROPER MOTION OF THE COMPONENTS OF 61 CYGNI.

S. W. BURNHAM.*

FOR THE MESSENGER.

I have never been able to find in the micrometrical observations of 61 Cygni any evidence of physical connection between these two stars, or rather that they probably form a binary system. The fact that the measures appear to show rectilinear motion only; and the further fact that the two stars have a different proper motion, at least tend to show that each is moving independently through space. At this time 61 Cygni certainly looks like a double star, although even now the distance between the star is much too great to indicate that it is probably binary; but a thousand years ago, taking the proper motions as substantially correct, no double star observer would have thought of looking at it a second time. The stars are now slowly separating, and it is easy to predict what their appearance will be to the observers of a hundred years hence. We have no example of a well recognized binary where the distance between the components is anything like as large as that of 61 Cygni. All of the systems showing sufficient angular motion to make it certain that the stars are revolving about a common center of gravity, have comparatively small apparent distances. This is so well recognized that it has not been considered worth while, so far as the discovery of binaries is concerned, to record new objects where the distances of nearly equal components exceed two or three seconds; and it is equally certain that stars in rapid motion will be found only where the minimum distances are much less than 1″. Just what should be inferred from stars having nearly the same proper motion, and in the same direction, perhaps no one is prepared to say at this time. There are many examples in the

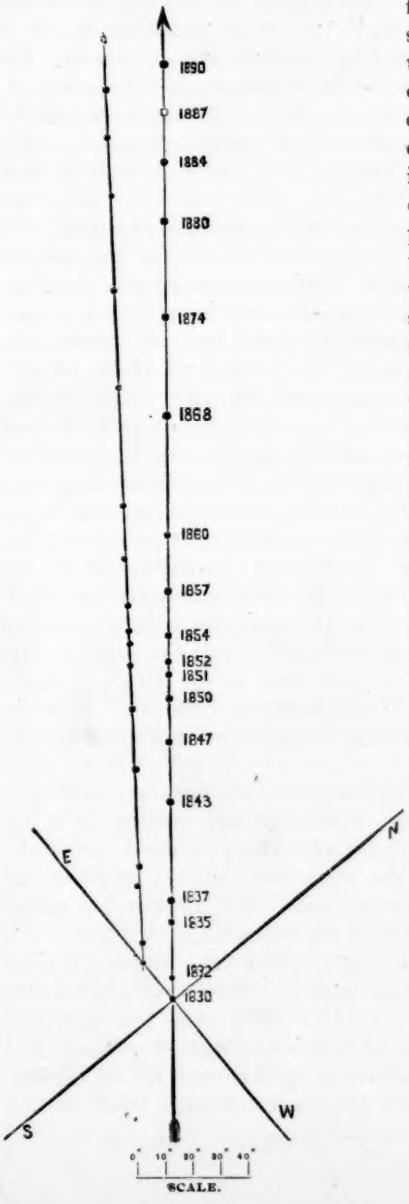
*Astronomer, Lick Observatory.

heavens of this common movement. Some of the stars, like 61 Cygni, are apparently near each other; while others, like those of the Great Dipper, are widely separated, and no one would think of suspecting that they had an orbital motion with reference to each other, although they, and the components of 61 Cygni, may be moving around some common central point.

If the measures of 61 Cygni, commencing with the earliest observations, are carefully platted, they will be found to represent, as nearly as measures can which are more or less in error, rectilinear motion. Of course some of the measures will lie on one side or the other of any line that can be drawn; and if some of the measured distances near either end of the line are a little too small, as is quite likely to be the case, they will give the whole series the appearance of a curve. I have platted in this way scores of stars where there was no suspicion of anything but proper motion, and very rarely, if ever, found an instance where the measures as a whole were so well represented by a straight line. When the relative accuracy of the several measures is taken into account, by considering the times at which the observations were made, the instruments used in the work, the number of nights contributing to the mean results, and particularly the experience of the observers, it is not difficult to draw a line which will represent the motion of the star with all the accuracy attainable from the given data.

Until recently I have never measured 61 Cygni, for the reason that much more time has been given to measures of this pair than its importance as a double star warrants, when so many far more interesting systems have been either very imperfectly followed, or almost wholly neglected. In order to see where the present place of the secondary star would be on the line representing its apparent movement, I have made within the last two or three weeks a set of measures on four nights with the 12-inch telescope. These measures give for the distance 21″.15, and the position-angle 121°.9 (1890.87); and represent as well as could be desired the change due to the proper motions of the two stars.

Two ways may be employed to show graphically from the measures the several positions of the components. The first and the one generally used, is to treat the primary star as



fixed during all the observations, and lay off the angle and distance of the companion at each epoch. In this case the companion, if it has no motion of its own, will have an apparent motion equal to the real proper motion of the principal star and in the opposite direction. The other plan is to plat the measures with the primary shifted along the line of its proper motion by the exact amount of its displacement during the interval between successive observations; in other words giving the two stars the exact places they actually occupy in the heavens at every measure. This method has a great advantage over the other when the proper motion, as in the case of 61 Cygni, is accurately known. I have used both in this case, and give here the latter diagram, which was made on a scale of $20'' = 1$ inch. The angles were carefully laid off to the nearest tenth of a degree, and the distance to the nearest tenth of a second. The

latest determination of the annual proper motion of the principal star is given as 5″.196 in the direction of 51°.5, and this value was used in platting the measures. The measures from 1830 to 1874 inclusive are by Σ and *O*Σ; those of 1880 and 1884 are by Hall; 1887 by Schiaparelli; and 1890 my own measures previously referred to. The original diagram when completed was reduced in the camera to the size given here.

It will be seen that these measures give not the least indication of departure from rectilinear motion in the smaller star. Indeed, they could not better represent absolute motion in a right line. We have all sorts of measures of this pair, good, bad and indifferent; and I have no doubt any one having a fair acquaintance with the work of the numerous observers who have measured this pair, could readily select by inspection a series of measures which certainly fail to give rectilinear motion, and probably would give an apparent curve in one direction or the other. In dealing with questions of this kind, it is better to rely altogether upon the observations of the best and most experienced observers, and therefore, I have used the Pulkowa measures for the entire period covered by them. It was impossible to show Bradley's position of 1753 on this diagram without making it on too small a scale when reduced to suit the page of this journal; but this position was used in the diagram made with the principal star considered as fixed, and it is in perfect harmony with the rectilinear motion shown by the other measures.

The diagram given here furnishes an accurate and easy means of determining the relative proper motion of B by measuring the motion of that star along its path during the 60.2 years covered by the measures, and the angle which that line makes with the meridian. The annual movement is thus shown to be 5″.113 in the direction of 53°.5.

On several occasions during the last year or two, I have examined both components with the 36-inch refractor to see if any real double star could be discovered but they appeared to be perfectly round under the highest powers, and as the atmospheric conditions were favorable it was evident there was nothing left for the large telescope to do in this direction.

Professor Newcomb in speaking of the character of the motion of the components of this star, has briefly and forcibly stated the case, and his opinion upon this subject:

"The only conclusion open to us is that each of them describes an immense orbit around their common center of gravity, an orbit which may be several degrees in apparent diameter and in which the time of revolution is counted by thousands of years. Two thousand years hence they will be so far apart that no connection between them would be suspected."

I think this conclusion is fully warranted by all the evidence bearing upon the case; and that all attempts to compute an orbit for this pair must necessarily result in failure.

If this does not sufficiently appear from the measures already made, it will soon be apparent from measures to be made in the near future. A careful set of measures every five years hereafter will be all that is necessary in following 61 Cygni considered as a double star.

CLOSE BINARY STARS.

EDWARD C. PICKERING.*

FOR THE MESSENGER.

At the November meeting of the Royal Astronomical Society Mr. Fowler announced the discovery that the star α Lyræ was a close binary having a period of 24.68 hours. The maximum difference in the velocity of its componets as derived from the doubling of the lines in its spectrum was 370 miles. Confirmation of this discovery is very desirable, since the star would then become one of the most interesting objects in the sky. Accordingly the large collection of photographs of the Henry Draper Memorial has been carefully examined. Seventy photographs of the spectrum of α Lyræ were found, the first one being taken on October 21, 1886. Many of them were taken with 4 prisms of 15° each, and showed excellent definition; a twentieth part of the separation of the lines as observed by Mr. Fowler should be visible. Any given photograph might have been taken when

* Director of Harvard College Observatory.

the lines were single, but the chances would be thirty to one that this would not be the case. Of course the chances that all could be taken at these times would be infinitely small. Moreover, the interval between the successive photographs is not always a multiple of 12.34 hours. One of the photographs was taken October 12, 1890, four days after the star was seen double by Mr. Fowler, but its lines are single. In some photographs the lines are a little hazy and in two the lines appear closely double, but this often happens when the image is slightly out of focus and there is any spherical aberration in the lens or prisms. Since the news of the discovery reached Cambridge, twenty-two photographs have been obtained on the evenings of December 2, 4, 7, and 9, and on the mornings of December 8 and 10. All of them show the lines single except those taken on December 2, which were out of focus. It may therefore be regarded as proved that the orbit cannot have the simple character announced by Mr. Fowler. The observed doubling of the lines may be accounted for in three ways. First, by an error in the focus. This seems improbable since successive photographs taken November 1 showed a variation in the separation of the lines. Secondly, the orbit may be very elliptical, in which case the lines might be double for a few hours at periastron when the motion is rapid, remaining single for the rest of the time. As the lines were double on October 8 and November 1 the half period might be twenty-four days or any sub-multiple of that time. In this case the lines should be again double on November 25 and December 19, and perhaps on December 7 and 31. With a shorter period the binary character could scarcely have escaped detection. Thirdly, a great variety of appearances might be produced by the presence of a third body. Apparent irregularities in the doubling of the lines in η Ursæ Majoris suggest such an explanation. A circular orbit will not account for the observed changes in this star. On the other hand the variations of β Aurigæ seem to be very regular. An approximate reduction of a series of 130 photographs, extending from November 20, 1886, to December 9, 1890, indicates a period $3d\ 23h\ 36.7m$ and that the lines should be single about Greenwich noon on January 1, 1891.

HARVARD COLLEGE OBSERVATORY,
Cambridge, Mass., Dec. 12, 1890.

STARS HAVING PECULIAR SPECTRA.

New Variable Stars in Perseus, Triangulum and Hydra.

M. FLEMING.

[Communicated by E. C. Pickering, Director of Harvard College Observatory].

A list of interesting objects showing peculiarities in their photographic spectra, and resulting from an examination of the photographs of stellar spectra taken at Cambridge with the 8-inch Draper telescope, and at Chosica, near Peru, with the 8-inch Bache telescope, is given in the following table. The designation of the star is followed by its approximate position for 1900, its magnitude, the date on which the photograph was obtained, the instrument employed, and a brief description of the peculiarity in its spectrum.

Design.	R. A. 1900 h m	Dec. 1900 ° ′	M.	Date.	Instrument.	Description.
DM — 20°50	0 16.7	— 20 37	5.5	Oct. 15, 1890	Draper 8-in. tel.	III type.
DM + 54 431	1 53.0	+ 54 20	9.0	Nov. 19, 1889	" "	III type. Hydr. lines bright.
—— —— ——	1 55.1	+ 56 15	....	Nov. 3, 1887	Bache telescope	III type. Hydr. lines bright.
DM — 10 513	2 30.2	— 9 53	8.0	Nov. 5, 1890	Draper 8-in. tel.	IV type.
DM + 33 470	2 31.0	+ 33 50	9.2	Oct. 13, 1890	" "	III type. Hydr. lines bright.
DM + 56 686	2 33.9	+ 56 18	9.1	Nov. 17, 1890	" "	Bright lines.
DM + 56 731	2 44.8	+ 56 31	9.5	Nov. 17, 1890	" "	Bright lines.
A.G.C. 7191	5 59.4	— 6 42	5.8	Feb. 15, 1888	Bache telescope	F line bright.
" 17717	12 56.3	— 70 56	6.6	May 14, 1890	" "	F line bright.
" 18770	13 43.4	— 27 44	7.0	May 15, 1890	" "	III type. Hydr. lines bright.
" 18947	13 51.6	— 55 51	8.0	May 25, 1890	" "	IV type.
" 20554	15 4.8	— 69 42	6.2	May 26, 1890	" "	IV type.
" 22280	16 21.2	— 18 14	4.6	June 18, 1890	" "	F line bright.
H.P. 3321	19 16.0	— 16 8	4.7	Sept. 5, 1888	" "	F line bright.
DM — 10°5057	19 17.7	— 10 54	7.0	Nov. 5, 1890	Draper 8-in. tel.	IV type.
H.P. 3747	20 13.9	+ 34 28	4.4	Oct. 15, 1890	" "	F line bright.
DM + 36°4028	20 17.8	+ 46 36	9.5	Nov. 10, 1890	" "	Bright lines.
A.G.C. 30526	22 16.6	— 46 27	6.7	July 21, 1890	Bache telescope	IV type.

The spectrum of DM — 20° 50 (T Ceti) is that of a well marked III Type star and differs from that usually shown by variables of long period in that the lines due to hydrogen are not bright in its spectrum. DM + 54° 431 [in Perseus] is variable, having the approximate magnitudes 10.6, 11.4, 11.0, 9.1, 9.0, 9.4 and 9.0 on Nov. 3, 1885; Nov. 30, 1887; Dec. 1, 1887; Sept. 29, Oct. 30, Nov. 19 and Nov. 19, 1890 respectively. The last two magnitudes were derived from a spectrum plate and a chart plate taken on the same evening. The star [in Perseus] whose position for 1900 is in R. A. $1^h\ 55^m.1$, Dec. $+ 56^\circ\ 15'$ is variable; approximate magni-

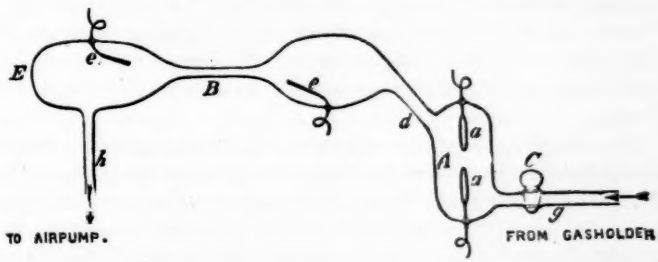
tudes < 15.2, 9.2, 9.3, 9.9, 12.2, 13.5 and 13.4 on Nov. 3, 1885; Nov. 3, 1887; Nov. 30, 1887; Dec. 1, 1887; Sept. 29, 1890; Oct. 30, 1890 and Nov. 19, 1890 respectively. DM + 33° 470 [in Triangulum] is variable. The variability of this star was discovered and measured at this Observatory on Oct. 16, 1890 and the approximate magnitudes 7.5, 9.2, 7.1, 6.8, 7.3, 7.2, and 7.1 obtained for Nov. 7, 1887; Jan. 16, 1888; Dec. 31, 1889; Sept. 25, Oct. 13, Oct. 15, and Oct. 17, 1890. In the Wolsingham Observatory Circular, No. 27, of Nov. 10, 1890, the Rev. T. E. Espin announces his discovery of this star and says that it is "probably variable." DM + 56° 686, + 56° 731 and + 36° 4028 have a spectrum resembling that of the stars discovered by Wolff and Rayet. The first two probably form part of a group similar to the one in Cygnus as several other spectra in the same region appear to show bright lines but are too faint to be seen distinctly. DM + 36° 4026 may be included in the Cygnus group. A. G. C. 7191, 17717, 22280, H. P. 3321, and 3747 have a spectrum similar to that of δ and μ Centauri. Of these A. G. C. 22280 (χ Ophiuchi) and H. P. 3321 (υ Sagittarii) are the most remarkable. χ Ophiuchi has additional bright lines. In υ Sagittarii the hydrogen lines are so fine as to be almost lost, other dark lines equally strong being present. Additional bright lines are also visible. A. G. C. 18770 (in Hydra) is variable; approximate magnitudes 9.7, 9.5, 10.4, 7.4 and 8.1 obtained from photographic charts taken June 14, July 5, July 12, 1889; May 6, and May 28, 1890. The fourth type star, Dunér II, 39 (DM — 5° 4858) has been measured on seven photographic charts giving the approximate magnitudes 8.9, 9.0, 9.1, 8.2, 8.1, 8.2 and 8.1 on June 26, July 20, Aug. 20, Oct. 22, Oct. 28, Nov. 4, and Nov. 18, 1890. Although the range of variability is not great, as seen from the above magnitudes, the variability of this star is undoubted since it appears brighter than adjacent stars on some of the charts and fainter than these stars on others.

In THE SIDEREAL MESSENGER, IX, 379, the star whose spectrum is announced as consisting mainly of bright lines, should be A. G. C. 15220 magnitude 8¼, whose approximate position for 1900 is in right ascension $11^h\ 2.3^m$ — 64° 58′ and not A. G. C. 15177.

Harvard College Observatory,
Cambridge, Mass., Dec. 11, 1890.

THE SPECTROSCOPIC PROPERTIES OF DUST.

The suggestion that the auroral spectrum, the principal ray in the spectrum of nebulæ, and other rays of unknown origin, might be due to meteoric dust induced us to investigate the problem whether solid particles of sufficient minuteness would act like gaseous molecules in an electric discharge and become luminous with their characteristic special radiation. The dust we employed was that thrown off from the surface of various electrodes by a disruptive discharge, and it was carried forward into the tube of observation by a more or less rapid current of air or other gas. The arrangement will be best understood from the annexed diagram, which represents a section of the glass vessel which was the principal part of the apparatus. *A* repre-



sents a bulb in which were the electrodes *a*, *a* to give the dust, connected by a widish tube *d* with the tube for observation *B*. The end *E* was blown clear, so that the narrow part of *B* could be observed end-on. The electrodes *e*, *e* were of platinum. The tube *g*, passing from *A* to the supply of gas, was fitted with a glass stopcock *C* for regulating the intake, and the tube *h* led from the distant end of *B* to the air-pump. The air-pump was a large one worked by a gas-engine capable of keeping the pressure down to a few millimetres, even with a considerable leakage. Observations were made of the discharge in *B* at various low pressures, sometimes with, and at other times without, a Leyden jar

* By G. D. Liveing M.. A., F. R. S., Professor of Chemistry, and J. Dewar M. A., F. R. S., Jacksonian Professor, University of Cambridge. Received August 16, 1890.

in circuit. The sparks in *A* were generally taken with a jar, and there was ample proof, if proof were needed, of the dust derived from the electrodes, since it formed a visible deposit in the tube *d*, in the first bulb of B, and even on the end *E*. The air or other gas passed into *A* was filtered through cotton-wool to remove all dust before admission to the apparatus.

Various metals were used as electrodes in *A*, magnesium, iron, manganese, cadmium, fused calcium chloride, metallic sodium in a little glass cup on a platinum wire, and fragments of the Dhurmsala meteorite; but in no case could the rays of any of the subtances employed be seen in the discharge through *B*, either when a Leyden jar was in circuit or not.

Incidentally, we found that magnesium electrodes were not so good as some of the other metals for these experiments, because the apparatus was never wholly free from traces of air, and lines or bright edges of bands of nitrogen fall very near the most characteristic lines of magnesium, and with small dispersion might easily be mistaken for them.

Air, hydrogen, carbon dioxide, and oxygen, were successively used as the gases passing through the apparatus, and at various pressures from 2mm. up to 20, and, in some cases, up to 40mm., but with the same result; no rays, due to the electrodes in *A*, could be detected in *B*. Even when one of the electrodes in *A* was sodium, and the sodium rays, orange, yellow, citron, green, and blue, were brilliant in the spectrum of *A*, not even the *D* lines could be detected in *B*. We should have expected that some traces of sodium *in the state of vapour* would have been carried by the stream of hydrogen into *B*; but it seems that it was not so; nor could the apparent absence of rays due to the dust, be ascribed to mere faintness in their light, for we took photographs of the spectrum of *B*, and found that even lengthened exposures produced no evidence of rays due to the dust; nor could it be ascribed to the character of the discharge in *B*, for the discharge was varied; sometimes *A* and *B* were in the same circuit; sometimes the discharge in *B* was from a separate coil, and even the powerful discharge from a large coil stimulated by a De Meritens' magneto-electric machine, was tried.

That abundance of dust was formed by the sparking in *A* was proved not only by the deposit in the tube, but by allowing the stream of gas at atmospheric pressure from the tube *h* (of course disconnected from the pump) to inpinge on a flame, when the characteristic flame-spectrum of the electrodes in *A* was at once manifest. When the gas used was hydrogen, and it was burnt in oxygen, the spectrum of the electrodes was particularly well seen; also when the gas was oxygen and led into a hydrogen flame.

That the dust was of extreme fineness and capable of being carried by a stream of gas to a great distance was proved as follows:—A stream of hydrogen, at ordinary pressure, was passed through the sparking tube with magnesium electrodes, and then through more than 100 feet of metal tube in a coil, and, finally, burnt as it issued. Before the sparking began there were no signs of magnesium in the flame; but when sparks had been passing between the magnesium electrodes for a short time, the magnesium spectrum was seen in the flame. It took 55 seconds for the gas to carry the dust through the long pipe, and when the sparking ceased it was again about the same time before the magnesium disappeared from the flame. It always appeared and disappeared sharply in correspondence with the sparking. Similar experiments, but with a shorter tube, were made with other metals, iron, sodium, lithium, etc., always with like results; also a current of oxygen was passed through the sparking tube and into a flame of hydrogen, and produced similar effects. Even aluminum, which does not usually show any part of its spectrum when used as an electrode in a vacuous tube, gave, when sparked in oxygen, dust which, when carried into a hydrogen flame, showed the characteristic bands of alumina.

Considering that a sensible amount of dust was deposited in the bulbs of *B*, we should have expected that some would be deposited on the electrodes *e*, *e* in that tube, and that the discharge from electrodes so coated would give the spectrum of the metal on their surface. There is no doubt that when no discharge was taking place in *B* the electrodes *e*, *e* did receive their share of dust; and, if it had been allowed to accumulate so as to form a coherent crust, it would have given its characteristic spectrum on first passing sparks in

B. But, so long as the dust is loose, the passage of a discharge instantly clears the electrodes of all dust, and seems to dispel all dust from the gas through which the discharge occurs. It is well known that an electric discharge in a vessel of air has the effect of clearing out of the air all the particles that serve as nuclei for the condensation of water; and we made several experiments with a view to determine whether a similar effect was produced on the dust in our tubes. The gas from the sparking tube was carried through a glass globe, and so on to the jet where it was burned; a wire connected with one pole of a Voss or Wimshurst electric machine projected into the interior of the globe, and a patch of tinfoil on the outside of the globe was connected with the other pole of the electric machine. So long as the Voss machine was not worked, the gas carried the dust from the sparking tube through the globe, and it was seen in the spectrum of the flame, or simply in the color of the flame when lithium was one of the electrodes; but, on working the machine so as to produce a silent discharge inside the globe, the flame, in one or two seconds, suddenly ceased to show the spectrum of the dust, and in the case of the lithium lost its red color. When the machine was no longer worked, the spectrum or color speedily reappeared, to vanish again suddenly when the machine was started afresh. When a narrow tube, with a piece of tinfoil outside and wire inside, was substituted for the globe, the like results ensued.

It appears, then, not only that dust, however fine, suspended in a gas will not act like gaseous matter in becoming luminous with its characteristic spectrum in an electric discharge, but that it is driven with extraordinary rapidity out of the course of the discharge. If, then, the spectrum of the aurora be due, not to the ordinary constituents of our atmosphere, but to adventitious matter from planetary space, we conclude that such matter must be in, or must be brought into, the gaseous state, or at least have its properties entirely altered from those it posseses at ordinary temperatures, before it becomes luminus in the electric discharge.

MASS OF 61 CYGNI.

NEWTON. M. MANN.

FOR THE MESSENGER.

In my article in the November MESSENGER on "Three Interesting Binaries," there was an error in the calculation of the mass of 61 Cygni which was not detected in time for correction. The elements there given really make the mass little more than one-half that of our sun. Considering that other stars that have been measured seem, without exception, much more massive—Sirius exceeding the sun at least sixty times, and the other doubles with noticeable parallax going two, three and four times our systen—this small result with 61 Cygni throws some suspicion on the determination of the orbit. In fact I have not pretended to determine it, nor can it be determined at present except within certain limits. Perhaps the matter is of enough interest to be presented somewhat more fully.

The companion star since observed by Bradley in 1753 has passed through 87° of its orbit, and its course for these 137 years is a curve subtended by 26 seconds of arc, showing a deflection of only about 1″.9 from a straight line. Still the curve is unmistakable. From the great mass of observations I deduce the following normal positions (Eq. 1890):

Year.	Angle.	Distance.
1750	31°.27	16″.42
1770	44 .83	15 .43
1790	59 .90	14 .85
1810	75 .40	14 .97
1830	89 .88	15 .84
1850	102 .46	17 .32
1870	113 .04	19 .07
1890	122 .28	21 .14

There is no trouble in completing an ellipse from this curve. The trouble is that it can be made a part of so many different ellipses. In fact it permits of an orbit of any degree of eccentricity. But beside the fact that a low eccentricity is unusual in these objects, and therefore improbable in this case, there is the further consideration that the more the orbit approaches a circle the longer the period and the smaller the mass. Thus if we make the eccentricity so low as 0.185 the semi-major axis becomes 21″.53 and the period

amounts to 651 years. Taking parallax at 0″.5 we have the mass of the system, compared with ours: $(21.53 \div .5)^3 \div (651)^2 = .188$—less than $\frac{1}{5}$ the sun; which is altogether improbable. If we raise the eccentricity to 0.55 the semi-major axis rises to 25″.8 and the period falls to 446 years. This makes the mass 692 thousandths that of the sun. We must increase the eccentricity to 0.65 to bring the system up to the weight of ours. One of a dozen of possible orbits that I have worked out gives these elements:

Semi-axis major	28″.12
Eccentricity	0.661
Position of Node	163°
Inclination	70° 34′
Period	400.1 years

Mass, 1.11 times the sun.

So great an eccentricity is unlikely to exist, and we may set it down as tolerably sure that here is at any rate one system into which no more material has gone than into our own. It is a feeble boast, but still it is something, to say for the dignity of our luminary that there is one star which is probably inferior to him—a star the nearest to us in all the northern skies, and yet shining only with the fifth magnitude, hardly more than bright enough to be seen with the naked eye. What imagination then shall reach to the massiveness of first magnitude stars which show no sensible parallax! We are not surprised to hear it said that they are 40, 60 or 100 times our sun.

OMAHA, Dec. 1890.

ASTRONOMICAL SOCIETY OF THE PACIFIC.

Meeting Nov. 29, 1890.

The regular meeting was held in the Young Men's Christian Association Hall, the president, E. S. Holden, presiding.

The minutes of the last meeting were approved.

At a meeting of the Directors held prior to the regular meeting the following new members were duly elected:

General John Gibbon, United States army; Herman Schussler, L. Gilson, Dr. E. S. Clark, Fremont Morse, J. J. Gilbert, H. W. Faust, Lieutenant

J. P. Finley, United States army, all of San Francisco; Homer A. Craig and Thomas Prather of Oakland, Cal.; W. B. Hayes, Los Angeles; Maures Horner, F. R. A. S., Somerset, England; C. F. De Landero, Guadalajara, Mexico; Dr. G. Barroeta, San Luis Potosi, Mexico; E. B. Knobel secretary, R. A. S., Braintree, England; P. Noordhoff, Groninger, Holland; Dr. J. Munos Tesar, Caracas, Venezuela; H. F. Newall, Cambridge, England; Professor Martin Kellogg, Berkeley; L. A. Rockwell and Dr. G. A. Wood, Traver; G. J. Hicks, E. M., Staten Island; Professor M. P. Freeman, Tuscon; M. A. Veeder, M. D., Lyons, New York; G. N. Saegmuller, Washington, D. C., Professor B. G. Clapp, Fulton, N. Y.; John A. Parkhurst, Marengo, Ill.; Hon. Demas Strong, Brooklyn, N. Y.; Joseph S. Adam, Canaan, Conn.; James E. Ingraham, Sanford, Fla.; William A. Browne, Newton, Mass.

This brings the total membership to 312.

It was announced that the next meeting (January 31st, 1891) would probably be held in the permanent home of the society, the new building of the California Academy of Sciences, which is almost completed.

The following papers were presented to the meeting, most of which were taken as read:

a. The Law of the Solar Corona, by Professor Frank H. Bigelow, of the Nautical Almanac Office, Washington, D. C.

b. Coronal Extension, by C. M. Charroppin, S. J., University of St. Louis, Missouri.

c. Observations and Drawings of Saturn, 1879 to 1889, by Professor Edward S. Holden, Lick Observatory.

d. The Observatory of Swathmore College, by Miss S. J. Cunningham, Director.

e. The Kenwood Physical Observatory (Chicago), by George E. Hale, Director.

f. Work at the Lick Observatory 1888 to 1890, by Professor Edward S. Holden, Director.

g. An account of an experiment made to determine whether gravitation force, varies with the temperature, by A. E. Kennelly, of Orange, N. J.

h. Index Map of Moon, by Professor C. A. Young.

As the meeting was largely attended by the public and friends of the members Professor Holden gave a popular account of the "Work of the Lick Observatory" since the Observatory had been under his direction.

The meeting then adjourned.

CHARLES BURCKHALTER, *Secretary.*

THE CAUSE OF REFRACTION.

FOR THE MESSENGER.

At the meeting of the Astronomical Department of the Brooklyn Institute, on Nov. 10, 1890, Henry M. Parkhurst exhibited the following diagrams, to demonstrate that refraction of light is caused solely by the change of the wave lengths in passing into a more or less dense medium.

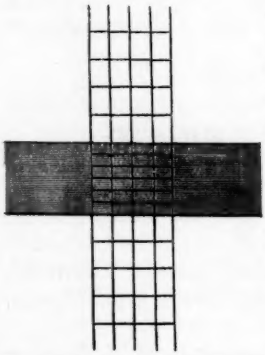


Fig. 1—RETARDATION OF WAVES.

In figure 1, a pencil of rays, consisting of successive waves, strikes perpendicularly upon the surface of a denser medium. The effect is to shorten the wave-length in a certain ratio. When the light reaches the rarer medium again, the waves are restored to their original length. That this is so, and that it is the cause of refraction, are shown in the following figures. The pencil is supposed to be magnified at least a thousand times, or each thousandth wave may be supposed to be represented.

In figure 2, the pencil of rays strikes obliquely upon a denser medium. The end of the wave which strikes first is shortened in the same ratio as before. The line of division runs rapidly along the edge, the portion of the waves within the glass being parallel and near together, and the portion outside the glass being parallel and at their original distance. Consequently the wave swings around, as shown. The opposite effect is shown upon emerging from the glass.

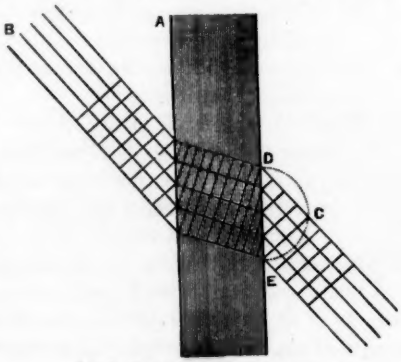


Fig. 2—REFRACTION OF WAVES.

In figure 3, the amount of the bending or refraction of the

PUBLIC LIBRARY,
No. 505 A88
DETROIT, MICH.

ray is shown to follow the well known law that the sine of refraction is proportional to the sine of incidence. The angle of incidence is represented by I, and making the width of the pencil at the surface of the glass radius, the sine of the incidence is represented by the end of the wave outside the glass, marked sine I, the opposite angle being manifestly equal to I.

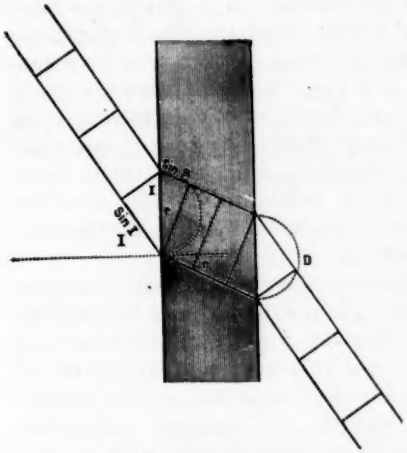


Fig. 3.—Law of Sines.

Again, the angle of refraction is represented by *r*; and employing the same radius as before, the sine of refraction is represented by the end of the wave within the glass, marked sine *r*, the opposite angle being manifestly equal to *r*. Since the shortening of the wave-length evidently produces exactly the observed amount of refraction, and explains the well known law, it is reasonable to conclude that it is the sole cause of refraction. The same principle also applies to the emergence of the ray. Since in emergence the outer angle of the ray must be a right angle, it must be situated in the dotted semicircle shown. See Euclid, Book III., Proposition 31.

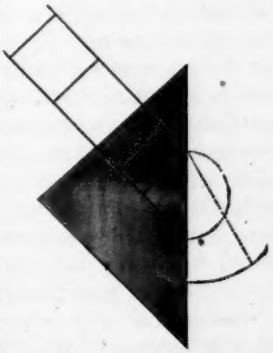


Fig. 4.—Total Reflection.

In passing through a prism, it sometimes happens that the extension of the wave-length carries it outside of this semicircle, as shown in figure 4. The extension of the upper end of the wave not only swings the ray around parallel to the face of the prism, but beyond that; so that the ray is forced back into the prism. In this case there is a total reflection of the light at that surface, it being impossible for a single ray to emerge.

STRANGE ATRONOMICAL COINCIDENCE.

E. E. BARNARD.*

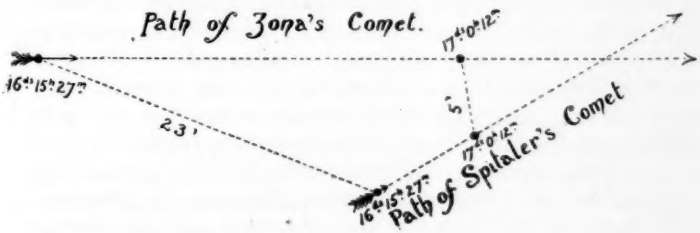
It is very seldom that coincidences of a startling nature occur in the astronomical world. Perhaps this is due in the main to the fact that nearly all things astronomical are subject to exact calculation, and there is nothing more chilling to the ardor of the average fabricator of coincidences than an array of facts and figures. There has very recently occurred, however, a most wonderful coincidence that must startle even the astronomical world, and this, stangely enough, instead of being frowned down by facts and figures, is strongly supported by them.

On the 15th of November last Professor Zona of the Palermo Observatory, in Italy, discovered a comet in the Constellation Auriga. It was moving rapidly to the west and north. On the following night (November 16th), while observing the position of this comet with the great twenty-seven-inch telescope at Vienna, Dr. Spitaler discovered another and fainter comet in the field of view with it; the motion was in the same direction as that of Zona's. Upon the announcement of the discovery of two new comets so close to each other astronomers naturally concluded that they were parts of the same comet and therefore were traveling through space together. It was, however, soon seen that there was no relationship whatever between the two, for Zona's comet rapidly left the other far behind, passing nine hours after Spitaler's discovery within five minutes of arc (one-sixth the apparent diameter of the moon) of the Vienna comet, so that the two must have appeared in the telescope as a double comet. By the night of the 17th, when Zona's comet could first be observed in America, they were some 2 degrees apart, and therefore the fainter one would have escaped discovery. They are now (December 10th) 2 hours apart in right ascension and differ 4 degrees in declination, and while one is moving southwards the other is keeping up its northerly motion.

Anyone familiar with the discovery of comets and the

* Astronomer at Lick Observatory.

comparative scarcity of the same, and who can appreciate the vast expanse of the heavens, in which the average comet is the merest speck, will recognize in this discovery of two new comets within a few minutes of each other and in no way physically connected, as one of the most remarkable coincidences ever known. There is no record of any two comets, not physically related, ever having been seen within a degree of each other, and there are many millions of chances against the discovery of two such comets so close together as were Zona's and Spitaler's, and we may safely say that it will never happen again.



I have made a diagram of the paths showing the positions of the two comets at the time of Spitaler's discovery, Nov. 16 days, 15 hours, and 27 minutes, Greenwich mean time, when the two were separated by 23 minutes of arc, and at 24 hours, 12 minutes when the nearest approach (5 minutes of arc) occurred.

These two comets are being regularly observed at the Lick Observatory. Neither is bright. Spitaler's is exceedingly small and faint—the merest speck of haze moving slowly among the stars. Its orbit has not yet been computed, but there is no doubt, from its appearance and slow motion, it must be very distant from us.—*The Examiner, San Francisco, Dec. 14, 1890.*

Mount Hamilton, December 10, 1890.

The Washington Observations for 1884. Besides the usual observations that receive attention each year at the Naval Observatory, the volume for 1884 contains the second edition of the Yarnall catalogue, the list of stars in which numbers 10,964, and embraces a range of observation from 1845 to 1847. This important piece of work has been previously referred to in this journal.

DR. KARL LUDWIG HENCKE.

PROFESSOR WILHELM FOERSTER.

Karl Ludwig Hencke was born at Driesen, a small borough in Newmark, April 8, 1793. He died at Merienworder Sept. 21, 1865, at the home of his son-in-law whither he had gone for a visit. His entire life was spent in Driesen and his occupation was post clerk at that place.

In his fourteenth year he became a successful applicant for a position in the post service. A short interruption to his service in this department occurred during the war of 1813 in which he served as a volunteer. But after the battle of Lutzen in which he received mention for his valor, and in which he was wounded, he found it was necessary to return to his position in the post service on account of his wound. Here he remained until 1837 when he received his well merited release with a yearly pension of 225 thalers.

From this time Hencke devoted himself to science. As early as Christmas, 1821, notwithstanding the requirements of his position, he furnished himself with a telescope of the Frauenhofer make, which cost more than 100 thalers, and with the instrument throughout the year, he combined the nightly post service with service to the Urania. Notwithstanding a very small amount of schooling, Hencke obtained a wonderful outlook over the astronomical knowledge of the time, and by his own astronomical activity obtained a place for which was needed great proficiency and stern perseverance and energy, and this the specialist some times loses in the intricacy of the problems and the deep absorption in one object.

The history of knowledge is rich in like peculiar interesting cases, in which the true, strong work of the specialist has furnished the indispensible groundwork for consequent proficiency. Our post clerk now began definite study in the starry heavens. He had the aid of Bode's guidance to the knowledge of the starry heavens, and also soon after furnishing himself with a telescope, which, in a certain way gave him a place among astronomers, he was presented to the Director of the Berlin Observatory and received his counsel.

He soon desired an accurate and full star chart in which might be found all the stars visible in his telescope. A skillful eye, and an unusual degree of accuracy in estimation aided him in establishing the place and magnitudes of the stars which he indicated upon his chart.

Directly after the invention of the telescope (1608), there was a belief that beyond the stars visible to the naked eye, the faintest of which were taken as sixth magnitude, the heavens were filled with innumerable fainter stars, and that especially the fainter cloud-like regions of the sky were composed of these stars crowded close together. With the help of his excellent Frauenhofer telescope, having the use of the existing star-charts, he constructed an extraordinarily accurate map of the heavens, and the eager zeal with which he searched the sky again and again surpassed what is usually devoted to a single branch of inquiry. Certainly the devotion of many astronomers to their work was not less than that of Hencke, but the separation of work into special departments was not so clearly developed as later, and Hencke stood alone in the concentration of his quiet life. So it happened that the great astronomical world of his day went to the small chamber of Driesen for light.

In a part of the sky which is pointed out on Hencke's chart, and also noted in one of the best academical charts of Berlin, Hencke saw, Dec. 8, 1845, for the first time, a small star which was fainter than the ninth magnitude, and which was mapped in none of the charts. He believed that it was a fixed star on account of its variable light, because having so often swept that part of the heavens, and having noted the variable light of the fixed stars, he believed that the star of Dec. 8 was also a variable star. Hencke sent an account of his discovery to Berlin to the *Vossische News*. A copy of it appeared in the following number on Dec. 13. On the day after Encke sent word from the Observatory of Berlin that the small star had changed its place among the fixed stars and was undoubtedly a planet. This knowledge Encke sent Hencke in a letter beginning with the words, "With the greatest pleasure and the most heartfelt good wishes do I write," etc.

And now recognition came from all sides to the plain man. The great gold Scientific medal was received from King

Frederick William IV; the Red Eagle Order IV. Kl. through the hands of Encke and Humboldt in March, 1846, with a yearly stipend of 300 thalers; the great Scientific medal from the King of Denmark; the title of Doctor of Philsophy from the University of Bonn, through Argelander, as well as praise and congratulations from Paris, London, etc. The earnest expressions of esteem were for Hencke as a man worthy of remark in himself and resulted in a true brotherly regard extended to him from Argelander, Encke, Humboldt and others. Encke was requested by the discoverer to name the new planet. Many names were proposed and finally the name Astræa was chosen.

Hencke was in no wise turned aside from his simple manner of life by the praise he received. He worked zealously, and July 1, 1847, announced the discovery of a second planet which received the name Hebe, and which brought him recognition anew, and a congratulatory letter from Gauss. This was the last of his independent discoveries. During the succeeding weeks in August, 1847, the English astronomer Hind in London, with a much stronger instrument, began to reveal the great belt of planetoids between the orbits of Jupiter and Mars, until now the number of the known planetoids of this group has reached 293* (the last discovered one being of the 12th magnitude). It is clear that Hencke's perseverance and success brought to light the asteroid system. For surely the discovery of the entire mass of the planetoids is not more noteworthy than the discovery of Astræa and Hebe, and these two threw much light on the theory of our planetary system.

Had Hencke possessed a much stronger glass and the special methods and contrivances with which numerous astronomers conduct their discoveries, he would have done more. But he remained to the end of his life busied with the construction of his star-chart and the comparison of the starry fields. It must be repeated that he discovered the planets, but there were soon so many astronomers at work in the field of his success that he was no longer aroused by the priority of discovery. He remained calm and quiet in the knowledge that he would be held worthy through all time on account of his exceedingly accurate star-chart.

* In December 1890, the number is 300.

Dr. Hencke was, as I have learned, eight years after the discovery of Hebe in the Berlin Observatory, an active man and of quick, merry temperament. He was a strong, independent thinker, almost radical in his tendency. Next to astronomy music and its theory interested him most.

His voice was heard in all the world-moving questions and in his youth he was regarded in the official world as a fearless and sometimes dangerous element. The energetic radicalism of his mind swayed all his opinions in his earlier years.

Rapid progress has followed Dr. Hencke's work. By cooperation and increase of knowledge many astronomical problems of his day have been solved. Photography has aided materially. Millions of faint stars are shown upon thousands of photographic plates. Now not only may we read the great book of the heavens at night, but also even in the day and with what pleasure do we gain therefrom the rich treasures of results and discoveries.—[*Translated from Himmel and Erde.*]

RESEARCHES ON THE MAGNESIA FLUTING IN CONNECTION WITH THE SPECTRA OF THE NEBULÆ.

GEORGE E. HALE.*

FOR THE MESSENGER.

After many years of continued investigation Professor Lockyer has formulated a very comprehensive theory of the universe. The spectroscopic study of meteorites, combined with a knowledge of cometary spectra, has led him to assume that all comets are composed of meteorites in swiftly moving swarms. Considering that these are drawn by the attraction of the sun from the regions of space, through which it is journeying with its attendant planets, he argues that innumerable meteor swarms must exist in space, and, in fact, give rise to the phenomena of stars and nebulæ. In this way it is easy to explain the temporary stars which suddenly shine out with great brilliancy, and as suddenly fade to insignificance. On Professor Lockyer's hypothesis such outbursts of light are caused by the collision of meteor swarms, and the rapid cooling of the stars cannot well be

* Kenwood Physical Observatory, Chicago.

explained except by assuming them to be composed of such small bodies. On the same theory the nebulæ are sparse swarms of meteorites, the temperature being low owing to the comparatively infrequent collisions of the members. Condensation toward a center is then caused by gravity, and the nebula becomes a star. More and more frequent collisions cause higher and higher temperatures, and finally we have the meteorites completely vaporized, and the hottest stars are the result. A cooling of the vaporous mass follows, the constituent elements are once more returned to the solid state, and a dark, cold body like the earth is the last actor in the stupendous drama of the heavens.

The spectroscope offers us the only means of putting this theory to the test. We must examine and compare the spectra of meteorites in vacuum tubes, in the nebulæ, and in the stars. If we find that a certain fluting of magnesium appears at the lowest temperature in a vacuum tube we should expect to find the same fluting visible in the coolest of the nebulæ. As the temperature in the vacuum tube rises, new lines and flutings become visible, and an increased number of collisions in the nebulæ should show the same lines and flutings. In fact, with the range of temperatures at our command we should be able to find a sequence of spectral changes matching those recorded at the telescope.

Such experiments as these have been carried on by Professor Lockyer. In his work with meteorites he has found a magnesium fluting visible at the lowest temperature of the vacuum tubes. In the nebula of Orion he has seen the brightest line exactly in the position of that in the tube. On this coincidence is based his belief in the meteoric constitution of the nebulæ, and this belief is the groundwork of his entire hypothesis.

In the initial number of the British Astronomical Association's Journal Mr. E. W. Maunder has given an interesting paper on "The Chief Nebular Line." After such a review of the numerous observations of Dr. Huggins, Professor Lockyer, Mr. Keeler and others, it is unnecessary to repeat them here, especially as those of most importance have recently appeared in the pages of THE MESSENGER. It has been shown by Mr. Maunder that the question of coincidence is by no means decided; that more light and even higher dis-

persion will be needed in future investigations. But while this is probably true there is one direction in which even small instruments can do valuable work. I refer to a study of the character of the nebular line. This, taken in connection with a knowledge of the exact nature of the magnesia fluting, may well lead to conclusions of great weight.

It may be of interest here to mention the opinions of several well-known observers of the nebulæ. In each case the original publication is referred to.

1864. Huggins (*Phil. Trans.* 1864, p. 441). Dumb-bell Nebula. "This line appeared nebulous at the edges.

1866. Huggins (*Phil. Trans.* 1866, p. 385). Dumb-bell Nebula. "When the slit was made as narrow as the intensity of the light would permit, this bright line was not so well defined as the corresponding line in some of the other nebulæ under similar conditions of the slit, but remained nebulous at the edges." . . . H 4572. "The spectrum of this nebula consisted of one bright nebulous line of the same refrangibility as the brightest of the lines of nitrogen." . . . H 4627. "This bright line appeared by glimpses to be double. Possibly this appearance was due to the presence near it of a second line."

1866. Secchi (*Bullettino Meteorologico*, 1866). "The planetary nebula in Andromeda has the line above named, but the principal one is a little diffused."

1868. Huggins (*Phil. Trans.* 1868, p. 542). Orion Nebula. "I expected that I might discern a duplicity in the line in the nebula corresponding to the two component lines of the line of nitrogen, but I was not able, after long and careful scrutiny, to see the lines double. The line in the nebula was narrower than the double line of nitrogen; this latter line may have appeared broader in consequence of irradiation, as it was much brighter than the line in the nebula." . . . "I incline to the belief that it (the line in the nebula) is not double."

1871. Vogel (*Beobachtungen zu Bothkamp*, 1872, p. 59). Dumb-bell Nebula. "But the line here appears broader than in the spectra of the planetary nebulæ, and is in particular very ill-defined toward the violet end of the spectrum."

1872. Huggins (*Proc. R. S.*, v. 20, p. 383) Orion Nebula. "With spectroscope B (two compound prisms) and eye-pieces 1 and 2, (5.5 and 9.2 diameters) the slit being made very narrow, this line was seen to be very narrow, of a width corresponding to the slit, and defined on both edges, and undoubtedly not double. The line of nitrogen when compared with it appeared double, and each component nebulous and broader than the line of the nebula."

1874. Huggins (*Proc. R. S.*, v. 22, p. 252), Orion Nebula. "In the simultaneous observation of the two lines it was found that if the lead line was made rather less bright than the nebular line, the small excess of apparent breadth of this latter line, from its greater brightness, appeared to overlap the lead line to a very small amount on its less refrangible side, so

that the two lines appeared to be in a straight line across the spectrum." (With two compound prisms, and eye-piece magnifying 16 diameters.)

1877. Bredichin (*Annals de l'Observatoire de Moscow*, v. 3, p. 120). "In this case (wide slit) the line appeared like a band, a little more defined toward the red."

1884. Maunder (*Greenwich Spectroscopic Results* 1884, p. 5), Orion Nebula. "The line λ 5005 was examined with this latter dispersion, (two prisms) the slit being very narrow, and was seen to be a single line. None of the lines in the spectrum of the nebula, are however, very sharp, λ 5005 showed a faint fringe mainly on the side nearer the blue."

1888. Lockyer (*Meteoric Hypothesis*, p. 317). Orion Nebula. "The image of the nebula being allowed to float slowly over the slit, I distinctly got the impression that the line in question varied in its behavior from the other lines, and that at the points where it was brightest it extended most towards the blue end of the spectrum. The observations were repeated at Kensington by Mr. Fowler, Demonstrator of Astronomy, and by Mr. Baxandall, and they arrived at the conclusion that the chief line had a decidedly fluted appearance."

1888. Taylor (*Monthly Notices*, v. 49, p. 124), Orion Nebula. "The 5001 line is by far the brightest in the spectrum. It is never seen sharp, but, with the narrowest slit, always has a fluffy appearance, this being much more marked on the blue than on the red edge. This was most carefully examined for evidence of structure, but the line was always found to be single, and no decided evidence of fluting structure could be made out.

1880. Lockyer (*Meteoric Hypothesis p.* 317), Orion Nebula "I have more recently observed the spectrum of the nebula in Orion with my 30-inch reflector at Westgate-on-Sea, using an enlarged form of pocket spectroscope with a dispersion which does not split D, and the observation is, to my mind, final. I found that in certain parts of the nebula the lines were knotted, and in others broken; but in the former case, whilst the F line thickened equally on both sides, the chief line thickened only on the more refrangible side . . . This was confirmed by Messrs. Fowler and Baxandall at Kensington, with the 10-inch equatorial on the 31st October and 1st November, 1889, and again by Mr. Fowler, with the 30-inch, on 2d November . . . Messrs. Fowler and Coppen have since made some very careful observations of the Ring nebula in Lyra, and also record the chief line as having a fringe on its more refrangible side. . . . In still more recent observations with a siderostat the chief line was noted by Mr. Fowler and Lieutenant Bacon to have a decided fringe on the more refrangible side."

1889. Huggins (*Proc. R. S.* v. 46, p. 50), Orion Nebula. "My own observations of this line, since my discovery of it in 1864. . . . show the line to become narrow as the slit is made narrow, and to be sharply and perfectly defined at both edges."

1890. Huggins (*Sidereal Messenger*, August 1890, p. 310), Orion nebula. "We come to the conclusion that a marked feature of this line is its sharply defined character on the more refrangible side, we were unable under any of the conditions of observing to detect even a suspicion of any softening of the more refrangible edge of the line; much less the faintest indication of a 'flare' and certainly not the distinctive peculiarity of a 'flut-

ing.'". . . Liveing (quoted by Huggins, *loc. cit.* p. 311), Orion Nebula. "The line always appeared sharply defined on the more refrangible side, whether the slit were wide or narrow." . . . Copeland (quoted *loc. cit.* p. 313), Orion Nebula. "All the lines were just as broad as the slit; when the slit was wide open they were broad, and when the slit was closed slowly they gradually became narrower and narrower." . . . Young (quoted *loc. cit.* p. 314). Orion Nebula. "With the prism the brightest nebular line seemed absolutely *sharp*, and clearly defined on both sides; with the grating (14,438) the line was fainter, and I could not use so narrow a slit; the dispersion was much higher also; the line therefore was a little hazy, *but equally so on both sides.*"

1890. Keeler (*Publications A. S. P.*, No. 11). Orion Nebula. "With all these different degrees of dispersion (single prism, compound prism, and 14,438 grating) and also with the other spectroscope employed, the nebula lines appear to be perfect monochromatic images of the slit, widening when the slit was widened, and narrowing to excessively fine sharp lines when it was closed up. The brightest line showed no tendency to assume the aspect of a 'remnant of fluting' under any circumstances of observation, but had always the appearance characteristic of light emitted by a gas at low temperature and pressure."

It will be seen from these quotations that great differences of opinion exist as to the appearance of the nebula line. These can partly be accounted for by the different light-gathering power of the telescopes employed, and also by the greater or less dispersion of the spectroscopes. As Professor Lockyer remarks, the fluted appearance could best be seen with small dispersion; but although the fringe would be brighter in this case it would also be narrower, and the second nebular line would be so near the first as to interfere with delicate observation unless hidden by a wire in the eyepiece, as suggested by Dr. Huggins. But mere differences in instrumental equipment are not sufficient to reconcile all the observations. Probably the publication of untouched photographs of the line would be the only means of satisfying the opposing views, but here difficulties of a different nature arise.

It is evidently very desirable to know the precise character of the magnesia fluting, and especially the relative intensities of the maxima. This subject has been studied by Professor Lockyer at Kensington, and by the writer at the Kenwood Observatory. Professors Liveing and Dewar have exhaustively studied the cause of the fluting, but have not given special attention to the relative intensities of the maxima. Professor Lockyer states, "the compound fluting

of magnesium near λ 500 is very similar to that of carbon. It consists of a series of bright lines of gradually diminishing brightness and increasing distance apart toward the more refrangible end, and each has a fringe *on the more refrangible side.* The first maximum (the least refrangible) is brighter than the others, and the fringe close to it is brighter than the second maximum."* In all seven maxima were observed, and the wave-length of the first is given as 5006.5. In experimenting on the visibility of the fluting a piece of neutral tint glass was placed between the burning metal and the slit, and the intensity of the light reduced until the fluting was about as bright as the chief line in the Orion nebula. "Under these conditions, the 500 fluting is only faintly visible, and the secondary maxima entirely disappear." Another way of observing this was to hold a piece of magnesia in the oxy-hydrogen flame. With a certain proportion of gases the compound fluting was seen pretty bright. By changing the quantity of hydrogen the fluting was made to fade, and finally only the first maximum and its fringe were seen. Photographs were also made which showed the first maximum brighter than any of the secondary ones.

My own study of the fluting has been made with three different spectroscopes:—a Rowland concave grating of 5-feet focus and 14,438 lines to the inch; a large telespectroscope with telescope of 3 inches aperture, and a 4-inch Rowland 14,438 grating; and a small spectrometer with either a single glass prism, or a small Rowland grating. These instruments, with the exception of the spectrometer, are elsewhere described.† The work was largely photographic, the concave grating being generally employed. In all nearly one hundred photographs of the fluting have been obtained in the first or second order spectrum. Several series of plates were made with different widths of slit, varying from .001 to .04 of an inch. In each series the width of the slit was constant, and pieces of magnesium ribbon of decreasing length were burned before the slit, the plate-holder being moved down between each exposure. Thus seven photographs of the fluting are shown on a single plate, and the exposure of the strips decreases from one side of the plate to the other. If the longest

* Meteoric Hypothesis, p. 314. † Pub. A. S. P., No. 12.

exposure is just sufficient to show all the lines of the fluting, the fainter lines should disappear as the exposure decreases, and if the first maximum and a portion of the more refrangible shading is brighter than the secondary maxima, we should finally be able to obtain this line and shading alone.

When fully timed the photographs show the seven well known lines of the magnesia fluting and in addition six fainter lines in continuation of the fluting, but evidently distinct from it, as they do not follow the same law of increasing distances. Perhaps these are due to the impurities in the magnesium, but as yet this has not been investigated. Another still more refrangible group of seven faint lines is also well shown, as well as the triplet corresponding to the solar *b* lines. A complete discussion of the spectrum of burning magnesium is reserved for the present; we will only concern ourselves here with the relative intensities of the lines in the principal fluting. The following record of a single plate will show how the lines disappear in a particular case.

Plate No.	Length Mg. Ribbon.	No. Lines Visible.	Width Slit.	Order
E 26	1 inch	6	0.002 in.	1
"	⅞ "	5	"	"
"	¾ "	4	"	"
"	⅝ "	3	"	"

The disappearnace of the fainter lines in this case is seen to be perfectly regular, but it must not be inferred that this regularity continues. On the contrary the first three lines seem to differ materially from the other four, and out of the large number of photographs already made not one shows the head line alone, while the first two lines are shown alone in but a single instance. A number of photographs made by a different method give almost identical results, and show no variations among themselves. During the exposure a screen moved by clock-work slowly rises before the plate, uncovering the lines of the fluting by degrees. Thus the bottom of the spectrum receives an exposure during the whole time that the ribbon is burning, and the exposure gradually decreases toward the top of the plate. This method has proved very successful. The first three lines of the fluting differ so little in height that it is difficult to pick out the longest, while the fourth is much shorter, and the rest of the lines fall off regularly. An examination of a number of

plates shows the first lines *very slightly* longer than the second, while the latter exceeds the third by about the same amount. It is not denied that the head line is somewhat brighter than any of the others, but the difference between it and the second line is certainly not great. Moreover the shading on the more refrangible side of the head line is by no means as bright as the brightest part of the second line.

These are the conclusions arrived at by a study of photographs, but it must be added that they are open to possible modifications. The plates used are ordinary, unstained dry plates made by the Seed Co., and their sensitiveness in different regions of the spectrum falls off gradually from the blue into the green. The curve does not fall rapidly at λ 5000, and I cannot think that a slightly decreased sensitiveness at the position of the first maximum can perceptibly effect the results. Even if there were such an effect the first three lines could not differ from the others in so marked a way, as the fall in the curve is perfectly regular. Unfortunately the curve of our plates stained with erythrosin has a minimum in the green at about this point, and no advantage is gained by using them. Moreover, eye observations with the various spectroscopes bear out the same conclusions. When the light from the burning ribbon is cut down by dark wedges etc., the first three maxima disappear almost simultaneously, and I have not yet been able to see the head line alone without traces of the rest of the fluting. The bearing of the these experiments upon the spectra of the nebulæ is obvious. It is hardly to be supposed that the light would be such as in all cases to show the chief line more brilliantly than any other line in the spectrum, while at the same time all the secondary maxima are entirely invisible. If the second and perhaps the third lines of the fluting can be found in the spectra of the nebulæ the presence of magnesia will no longer be questioned. In the lack of such observations there is room for reasonable doubt.

KENWOOD PHYSICAL OBSERVATORY,
Chicago, Dec. 20, 1890.

Cheapest Form of Light is the title of a paper issued by Professor S. P. Langley and F. W. Very, of Allegheny Observatory which is printed in full in the *American Journal of Science*. The object of the paper is to show by the study of the radiation of the firefly that it is possible to produce light without heat other than in the light itself.

CURRENT CELESTIAL PHENOMENA.

THE PLANETS.

Mercury will be at inferior conjunction with the sun Jan. 13 at $11^h\ 31^m$ A. M. central time. He will be at greatest western elongation, 25° 40′ west from the sun, on the morning of Feb. 6. He will be visible to the unaided eye on several mornings about that date. To see him at that time one must look toward the southeast about an hour before sunrise.

Venus will be at her greatest brilliancy for the present season on Jan. 8, when she is also at perihelion. At that time the phase will be crescent, one-fourth of her apparent disk being illuminated. She may be seen toward the southeast in the morning about three hours before sunrise.

The only observer who, so far as reported, was successful in observing Venus near the time of inferior conjunction Dec. 3 and 4, was E. E. Barnard, astronomer at Lick Observatory, the account of whose observations are given on another page. At Northfield we were unable, on account of cloudy weather, to see the planet until December 6, when the cusps of the crescent could be traced but little, if any, beyond the semicircle.

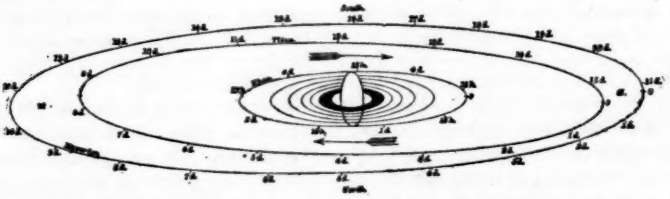
In the *Journal of the British Astronomical Association*, Vol. 1, No. 1, Oct. 1890, Miss A. M. Clerke gives an interesting review of Professor Schiaparelli's papers on the "Rotation Periods of Mercury and Venus." *L'Astronomie*, Dec. 1890, contains an article by Professor Perrotin, director of the Observatory at Nice, in which he gives the results of his recent observtions of Venus with the great equatorial at Nice. These observations were made in the daytime on 74 days between May 15 and Oct. 4, 1890. Sixty-one drawings were made during these observations, six of which are reproduced in *L'Astronomie* by wood engravings. They all show a dusky marking extending from north to south lying in the first drawings along the terminator, in the later ones gradually moving toward the west. In the later drawings there are several branches to the main dark area. The conclusions derived by Perrotin are entirely confirmatory of those reached by Schiaparelli, namely that Venus rotates upon her axis in the same time that she revolves in her orbit about the sun. The period may be anywhere between 195 and 225 days. The axis is very nearly perpendicular to the orbit.

Mars will be in the same position with reference to the sun in which he has been during the past month. His daily motion eastward and northward is just sufficient to make the time of his setting almost constant. The disk of Mars is now so small that but little of detail can be seen upon his surface.

Jupiter is too nearly in line with the sun to be well seen. He will be at superior conjunction Feb. 13. C. Duprat, at Tebessa, Algeria, reports that on Sept. 26 and the following day he was able to see Jupiter with the naked eye, 20 *minutes before sunset* (*L'Astronomie*, Dec. 1890.)

Saturn is in good position for observation after midnight. He may be readily recognized in the eastern part of the constellation Leo, by his brightness and his steady yellow light. The *Monthly Notices* for November, 1890,

has not yet arrived so that we cannot give our readers data concerning the satellites from Mr. Marth's ephemerides. We give this month a diagram showing the apparent orbits of the seven inner satellites as they are seen in an interesting telescope. By the aid of this diagram the observer can easily find the positions of the satellites on each day between the dates of eastern elangation.



APPARENT ORBITS OF THE SEVEN INNER SATELLITES OF SATURN, MAY 17, 1891, AS SEEN IN AN INVERTING TELESCOPE.
(The Vertical Scale is Twice the Horizontal One.)

Uranus will be at quadrature with the sun Jan. 21, and stationary in right ascension Feb. 4. He may be best observed from four to six in the morning. He is near the foot of Virgo, about 10° east from Spica and 2°.5 southwest from $\varkappa$ Virginis. A telescope of very moderate power will enable one to recognize this planet by its greenish-hued disk.

Neptune is now in his most favorable position for amateur observers, coming to the meridian a little after nine o'clock in the evening. It may be found in Taurus between the well known groups of the Pleiades and Hyades. It is about 3° west and ½° north of ε Tauri, the uppermost star in the V-shaped group of the Hyades. During this month it will be in the same field of view with two eighth-magnitude stars, from which it will be difficult to distinguish the planet except by its relative motion from night to night. Large telescopes will, of course, show the disk of the planet. On Jan. 1 Neptune will be almost directly north of the eastern star. Its motion will carry the planet almost directly toward the western star, by which it will pass on Jan. 9.

Date. 1891.	R. A. h m	Decl. ° ′	Rises. h m	Transits. h m	Sets. h m
MERCURY.					
Jan. 24	19 01.2	− 19 48	6 05 A. M.	10 46.1 A. M.	3 27 P. M.
Feb. 3	19 22.1	− 20 58	5 52 "	10 28.0 "	3 04 "
13	20 09.4	− 20 37	5 59 "	10 35.8 "	3 13 "
VENUS.					
Jan. 24	17 15.3	− 18 28	4 14 A. M.	9 00.8 A. M.	1 48 P. M.
Feb. 3	17 52.3	− 19 23	4 15 "	8 58.2 "	1 41 "
13	18 33.6	− 19 52	4 20 "	9 00.2 "	1 41 "
MARS.					
Jan. 24	23 57.0	− 0 46	9 41 A. M.	3 41.3 P. M.	9 42 P. M.
Feb. 3	0 23.9	+ 2 18	9 16 "	3 28.8 "	9 41 "
13	0 50.6	+ 5 18	8 52 "	3 16.2 "	9 41 "
JUPITER.					
Jan. 24	21 30.3	− 15 35	8 15 A. M.	1 15.0 P. M.	6 15 P. M.
Feb. 3	21 39.6	− 14 49	7 42 "	12 45.0 "	5 48 "
13	21 49.0	− 14 02	7 08 "	12 15.0 "	5 22 "

SATURN.

Date. 1890.	R. A. h m	Decl. ° ′	Rises. h m	Transits. h m	Sets. h m
Jan. 24	11 13.4	+ 7 15	8 27 P. M.	2 55.8 A. M.	9 31 A. M.
Feb. 3	11 11.4	+ 7 30	7 41 "	2 14.5 "	8 48 "
13	11 08.9	+ 7 48	6 58 "	1 32.7 "	8 07 "

URANUS.

Jan. 24	13 57.6	− 11 26	12 26 A. M.	5 43.5 A. M.	11 01 P. M.
Feb. 3	13 57.8	− 11 27	11 43 P. M.	5 00.5 "	10 18 "
13	13 57.6	− 11 26	11 03 "	4 21.0 "	9 39 A. M.

NEPTUNE.

Jan. 24	4 09.7	+ 19 22	12 31 P. M.	7 53.3 P. M.	3 16 A. M.
Feb. 3	4 09.4	+ 19 22	11 51 A. M.	7 13.7 "	2 36 "
13	4 09.3	+ 19 22	11 12 "	6 34.2 "	1 57 "

THE SUN.

Jan. 19	20 06.4	− 20 07	7 30 A. M.	12 11.0 P. M.	4 52 P. M.
24	20 27.5	− 19 09	7 27 "	12 12.4 "	4 58 "
29	20 48.2	− 17 51	7 22 "	12 13.4 "	5 04 "
Feb. 3	21 08.6	− 16 26	7 17 "	12 14.1 "	5 11 "
8	21 28.7	− 14 54	7 10 "	12 14.4 "	5 18 "
13	21 48.4	− 13 16	7 04 "	12 14.4 "	5 25 "

THE MOON.

Jan. 25	9 47.9	+ 19 10	5 36 P. M.	1 16.2 A. M.	9 02 A. M.
29	12 49.7	+ 0 32	9 46 "	4 03.8 "	10 32 "
Feb. 5	18 07.5	− 24 52	4 28 A. M.	8 53.0 "	1 15 P. M.
10	23 31.4	− 9 49	8 29 "	1 57.4 P. M.	7 38 "
15	4 03.3	+ 19 11	10 39 "	6 09.9 "	1 52 A. M.

Saturn's Satellites.

[Central Time; E = eastern elongation; I = inferior conjunction; W = western elongation : S = superior conjunction.]

JAPETUS.

Jan. 16	11.2 A. M. I.	Feb. 4	8.8 W.		

TITAN.

Jan. 17	10.9 P. M. E.	Jan. 29	11.1 P. M. S.	Feb. 10	6.2 P. M. W.
21	5.8 " I.	Feb. 2	9.6 " E.	14	9.4 " S.
25	7.7 " W	6	4.5 " I.		

RHEA.

Jan. 18	2.0 P. M. E.	Feb. 1	3.1 A. M. E.	Feb. 14	4.1 P. M. E.
23	2.3 A. M. E.	5	3.4 P. M. E.		
27	2.7 P. M. E.	10	3.8 A. M. E.		

DIONE.

Jan. 17	4.4 A. M. E.	Jan. 30	8.7 P. M. E.	Feb. 13	1.0 P. M. E.
19	10.2 P. M. E.	Feb. 2	2.4 P. M. E.		
22	3.7 P. M. E.	5	8.0 A. M. E.		
25	9.4 A. M. E.	8	1.9 A. M. E.		
28	3.1 A. M. E.	10	7.4 P. M. E.		

TETHYS.

Jan. 17	2.1 A. M. E.	Jan. 28	9.9 A. M. E.	Feb. 8	5.7 P. M. E.
18	11.4 P. M. E.	30	7.2 A. M. E.	10	3.0 P. M. E.
20	8.7 P. M. E.	Feb. 1	3.5 A. M. E.	12	12.3 P. M. E.
22	6.0 P. M. E.	3	1.8 A. M. E.	14	9.6 A. M. E.
24	3.3 P. M. E.	4	11.1 P. M. E.		
26	12.6 P. M. E.	6	8.4 P. M. E.		

Occultations Visible at Washington.

Date.	Star's Name.	Magnitude.	IMMERSION. Wash. Mean T. h m	IMMERSION. Angle f'm N. P't. °	EMERSION. Wash. Mean T. h m	EMERSION. Angle f'm N.P't. °	Duration. h m.
Jan. 17	B.A.C. 755	6.5	5 11	83	6 23.2	207	1 12
19	ω^1 Tauri	6.0	4 45	27	5 45.9	278	1 01
21	5 Geminorum	6.7	13 37	148	14 19.5	220	0 43
26	*i* Leonis	5.7	15 46	99	16 56.7	326	1 11
30	$\epsilon 5$ Virginis	6.1	12 04	197	12 18.8	222	0 15
30	I^2 Virginis	5.1	18 21	139	19 39.7	289	1 19
31	$\varkappa$ Virginis	4.2	14 10	104	15 21.5	327	1 12
Feb. 12	*f* Piscium	5.1	5 47	28	6 49.8	265	1 03
15	ω^1 Tauri	6.0	13 01	127	13 38.0	215	0 37

Minima of Variable Stars of the Algol Type.

[The times are given, to the nearest hour of Central Time, of only those minima which can be observed in the United States.]

U CEPHEI.

R. A.....$0^h\ 52^m\ 32^s$
Decl.....$+81°\ 17'$
Period.....$2d\ 11^h\ 50^m$

Jan. 19	2 A. M.
24	1 "
29	1 "
Feb. 3	1 "
7	midn.
12	"

ALGOL.

R. A.....$3^h\ 10^m\ 01^s$
Decl.....$+40°\ 32'$
Period.....$2d\ 20^h\ 49^m$

Jan. 19	midn.
23	9 P. M.
25	6 "
Feb. 11	11 "
14	8 "

λ TAURI

R. A.....$3^h\ 54^m\ 35^s$
Decl.....$+12°\ 11'$
Period.....$3d\ 22^h\ 52^m$

Feb. 2	midn.
6	11 P. M.
10	10 "
14	9 "

R CANIS MAJ.

R. A.....$7^h\ 14^m\ 30^s$
Decl.....$-16°\ 11'$
Period.....$1d\ 3^h\ 16^m$

Jan. 19	8 P. M.
20	11 "
22	2 A. M.
27	7 P. M.
28	10 "
30	1 A. M.

R CANIS MAJ. *Cont.*

Feb. 4	6 P. M.
5	9 "
6	midn.
8	3 A. M.
13	8 P. M.
14	11 "

S. CANCRI.

R. A.....$8^h\ 37^m\ 39^s$
Decl.....$+19°\ 26'$
Period.....$9d\ 11^h\ 38^m$

Jan. 13	10 P. M
Feb. 1	10 "

S ANTLIÆ.

R. A.....$9^h\ 27^m\ 30^s$
Decl.....$-28°\ 09'$
Period.....$7^h\ 47^m$

Jan. 16	11 P. M.
17	10 "
18	9 "
21	3 A. M.
22	3 "
23	2 "
24	2 "
25	1 "
25	midn.
26	"
27	11 P. M.
28	11 "
29	10 "
30	9 "
Feb. 3	3 A. M.
4	2 "
5	2 "
6	1 "
6	midn.
7	"
Feb. 8	11 P. M.

S ANTLIÆ. *Cont.*

Feb. 9	10 P. M.
10	10 "
11	9 "
15	3 A. M.

δ LIBRÆ.

R.A.....$14^h\ 55^m\ 06^s$
Decl.....$-8°\ 05'$
Period.....$2d\ 07^h\ 51^m$

Jan. 18	3 A. M.
24	3 "
Feb. 1	3 "
7	2 "
15	2 "

U CORONÆ.

R. A.....$15^h\ 13^m\ 43^s$
Decl.....$+32°\ 03'$
Period.....$3d\ 10^h\ 51^m$

Jan. 13	3 A. M.
20	2 "
26	midn.
Feb. 5	3 A. M.
12	midn.

Y CYGNI.

R. A.....$20^h\ 47^m\ 40^s$
Decl.....$+34°\ 15'$
Period.....$1d\ 11^h\ 57^m$

Jan. 15	8 P. M.
18	8 "
21	8 "
24	8 "
27	8 "
30	8 "
Feb. 2	8 "
5	8 "
8	8 "
11	7 "
14	7 "

Phases and Aspects of the Moon.

			Central Time. d	h	m	
First Quarter	1891	Jan.	17	12	18	A. M.
Full Moon	"	"	24	6	25	P. M.
Apogee	"	"	27	9	48	A. M.
Last Quarter	"	Feb.	1	10	42	P. M.
New Moon	"	"	8	8	12	"
Perigee	"	"	9	6	18	A. M.

COMET NOTES.

Comet 1889 V. Mr. Dayton C. Miller, now instructor in mathematics in the Case School of Applied Science, at Cleveland, Ohio, has computed the following elliptic elements of this comet, from observations made by himself with the 23-inch equatorial and square bar micrometer of the Halsted Observatory, Princeton, from Nov. 14, 1889, to March 8, 1890. Three normal places, Nov. 15.5, Dec. 15.5 and Jan. 14.5, were used in computing the elements. The investigation of the orbit and historical sketch of the comet, on the supposition of its identity with Lexell's comet of 1770, were presented as a thesis for the degree of Doctor of Science to the Faculty of the college of New Jersey, Princeton, in 1890.

$$\begin{aligned} T &= 1889 \text{ Sept. } 28.27186 \text{ G. M. T.} \\ \pi &= 0^\circ\ 44'\ 02''.77 \\ \Omega &= 18\ \ 05\ \ 55\ .67 \quad 1890.0 \\ i &= 6\ \ 04\ \ 02\ .23 \\ \varphi &= 27\ \ 15\ \ 38\ .18 \\ \log a &= 0.5537124 \\ \log \mu &= 2.7194381 \\ P &= 6.7697 \text{ yrs.} \end{aligned}$$

Middle place, Obs.—Calc.

$$d\lambda \cos\beta = +0''.19 \qquad d\beta = +0''.05$$

Comet f 1890 (Spitaler) has been looked for at many places but seen at very few. Professor Lewis Swift saw on Dec. 8 an object which on Dec. 14 was not in the same place. Professor Barnard at Lick Observatory has observed this comet regularly since Dec. 6. He says that it has been exceedingly small and faint, but that it is now (Dec. 12) apparently getting somewhat larger and brighter. No elements have yet reached us.

Comet e 1890 (Zona) has been observed at many places. The best elements at hand are those by Mr. Wendell, which are given below.

Orbit and Ephemeris of Comet e 1890 (Zona Nov. 15.) From Zona's observation of Nov. 15 and my own of Nov. 22 and 28, I have computed the following orbit and ephemeris of Zona's comet:

Elements.

$$\begin{aligned} T &= 1890 \text{ Aug. } 7.10021 \text{ Gr. M. T.} \\ \pi - \Omega &= 331^\circ\ 26'\ 36'' \\ \Omega &= 85\ \ 29\ \ 8 \\ i &= 154\ \ 26\ \ 5 \\ \log q &= 0.31148 \qquad q = 2.0487 \end{aligned}$$

Ephemeris.

Gr. M. T.	App. R. A. h m s	App. Dec. ° ′	Log *r.*	Log *Δ.*
Jan. 1.5	2 3 46	+ 29 24	0.4279	0.3202
2.5	2 1 48	29 13		
3.5	1 59 55	29 2		
4.5	58 6	28 52		
5.5	56 21	28 41	0.4326	0.3416
6.5	54 42	28 31		
7.5	53 7	28 21		
8.5	51 35	28 12		
9.5	50 8	28 2	0.4373	0.3627
10.5	48 48	27 54		
11.5	47 31	27 45		
12.5	46 16	27 37		
13.5	45 6	27 29	0.4420	0.3829
14.5	44 0	27 22		
15.5	42 56	27 14		
16.5	41 54	27 7		
17.5	40 57	27 0	0.4467	0 4025
18.5	40 4	26 53		
19.5	39 12	26 47		
20.5	38 22	26 41		
21.5	37 36	26 35	0.4513	0.4214
22.5	36 54	26 29		
23.5	36 13	26 24		
24.5	35 35	26 19		
25.5	34 58	26 14	0.4560	0.4395
26.5	34 25	26 9		
27.5	33 53	26 5		
28.5	33 23	26 1		
29.5	32 55	25 57	0.4606	0.4568
30.5	32 29	25 53		
Jan. 31.5	1 32 5	+ 25 49		

The theoretical light of the comet on Jan. 31 will be less than half that on Jan. 1.

O. C. WENDELL.

Harvard College Observatory, Dec. 17, 1890.

Smith Observatory Observations. The following sun-spot observations were made with *helioscope* unless otherwise stated. They were taken by Charles E. Peet:

1890.	90° Mer. M. T.	Groups.	Spots.	Faculæ.	Seeing.	Remarks.
Nov. 18	2:55 p m	0	0	1	Poor.	Faculæ near SW. limb.
19	1:15 p m	0	0	0	Poor.	
20	1:15 p m	0	0	0	Fair.	
21	3:30 p m	0	0	0	Bad.	Seeing too poor to distinguish anything.
22	4:25 p m	0	0	0	Bad.	" " " " " "
23	2:30 p m	1	15	1	Fair.	One large spot with nuc. and penum.
24	1:45 p m	1	13	1	Fair.	Faculæ on NW. limb.
25	2:30 p m	1	11	2	Fair.	Faculous mottlings.
26	2:55 p m	1	19	0	Good.*	Four of the spots have nuc. and penumbra.
27	12:20 p m	1	13	1	Poor.	Faculæ on W. limb.
28	2:30 p m	1	17	1	Fair.*	Faculous mottlings near NW. and N. limb.
Dec. 1	9:40 a m	1	5	0	Poor.*	Group near NW. limb; 1 spot with nuc.
6	1:25 p m	1	2	0	Poor.	Group near SW. limb. [and penumbra.
8	12:55 p m	1	1	1	Good.	Faculous region about spot.
10	9:18 a m	0	0	0	Poor.	
14	3:10 p m	2	16	3	Fair.	Faculæ on E., SE. and NE.

* Projection on 20 cm. circle.

CHAS. A. BACON.

Carleton College Sunspot Observations. (Continued from page 468.)

1890.	Central Time.	Groups.	Spots.	Faculæ.	Observer.	Remarks.
Nov. 21	12:30 p m	0	0	0	C. R. W.	
22	10:40 a m	1	2	2 gr.	"	
24	2:20 p m	1	13	0	"	
25	12:40 p m	1	14	2 gr.	"	
27	10:20 a m	1			"	
28	10:30 a m	1	4		"	
Dec. 6	12:25 p m	1	1	2 gr.	"	One small spot surrounded by group of faculae SW. of centre. Group of faculae SE.—not prominent.
8	11:15 a m	1	1	1 "	"	One small spot very near W. limb surrounded by small bright group of faculae.
10	12:45 p m	1	1	1 "	"	Small spot on E. limb surrounded by small group of faculae.
11	12:45 p m	0	0	1 "	"	
12	12:20 p m	0	0	0	"	
16	12:20 p m	1	14	0	"	
17	12:20 p m	1	6	0	"	
18	12:45 p m	2	20	0	"	
19	12:35 p m	2	10	1 gr.	"	
20	12:40 p m	2	5	2 "	"	Large group of faculae on E. limb surrounding small spot.
22	11:10 a m	0	0	1	"	
23	12:40 a m	1	1	2 gr.	"	

Mount Holyoke Observatory. Sunspot Observations by Miss E. M. Bardwell.

1890	Eastern Time.	Groups.	Spots.	Faculæ.	Remarks.
Nov. 3	About 12.00.	0	0	0	
" 4		0	0	0	
" 5		0	0	0	
" 6		0	0	0	
" 7	12.30	1	4		Hazy.
" 10	11.00	1	6	1	Floating clouds.
" 13	3.00	2	9		
" 14	About 12.00.	0	1	2	
" 18		0	0	3	
" 19		0	0	1	
" 21		0	0	2	
" 22	12.00	1	4	2	
" 24	12.00	1	13		Too cloudy to see faculae.
" 25	12.00	1	24		Cloudy. Could not count all the numbers.
" 26	12.00	1	26		
" 27	12.00	1	25		
" 28	12.00	2	20	2	Largest spot 24,000 miles across.
Dec. 1	11.30	1	3	1	Faculae around spots.
" 2	11.00	2	5	1	Large and very bright faculae around spots.
" 9	12.00	0	1	1	
" 12		0	0	3	
" 13	12.00	2	9		Cloudy.
" 15	12.00	2	14	2	One group of faculae was very bright.
" 16	12.00	1			Very hazy. Many small spots. Could not count them.
" 19	11.30	2	10	3	

South Hadley, Mass.

Solar Observations, Alta, Iowa.

OCTOBER 1890.

Date.	Central Time.	No. of New		No. of Visible		Definition.	Remarks.
		Groups.	Spots.	Groups.	Spots.		
1	11.25 a m	0	0	1	2	Good.	Faculæ NW.
2	11.45 a m	0	0	0	0	Fair.	
4	11.25 a m	0	0	0	0	Good.	Faculæ on NW. limb.
6	5.20 p m	1	?	1	?	Poor.	Sun too low to count spots.
7	12.00 m	0	0	0	0	Poor.	Hazy.
14	11.30 a m	0	0	0	0	Good.	Faculae near W. limb.
16	11.25 a m	0	0	0	0	Good.	Clear Disc.
17	11.20 a m	0	0	0	0	Good.	Clear Disc. Aurora this evening.
18	11.15 a m	0	0	0	0	Good.	Clear Disc.
19	2.20 p m	1	3	1	3	Good.	Spots SE. limb. Faculae E.
20	12.00 m	0	3	1	6	Good.	2 large spots, others small. Faculae on E. limb.
21	11.30 a m	0	0	1	6	Good.	3 large spots, 1 spot with umbra and penumbra. Faculae around Group.
22	11.30 a m	1	?	2	11	Fair.	Slight haze. Could not count all small spots.
23	11.20 a m	0	6	2	17	Good.	Spots small. 1 large one.
24	3.45 p m	0	0	2	15	Fair.	Brilliant "bridge" across large spot.
25	11.30 a m	0	0	1	?	Poor.	Single glimpse through clouds.
26	4.30 p m	0	0	1	?	Poor.	Sun too near horizon to count spots.
30	11.20 a m	0	0	1	2	Good.	Faculae NW.
31	11.30 a m	0	0	0	1	Bad.	Hazy. Large spot is on W. limb disappeapearing by solar rotation.

No observations owing to clouds on the 3d, 5th, 8th to 13th, 15th, 27th to 29th.

NOVEMBER 1890.

1	11.30 a m	0	0	0	0	Poor.	Apparently Clear Disc.
3	11.25 a m	0	0	0	0	Good.	Clear Disc.
4	11.20 a m	0	0	0	0	Good.	Clear Disc.
5	11.20 a m	0	0	0	0	Good.	Clear Disc.
9	3.00 p m	1	3	1	3	Good.	Group about 2 days in SE. surrounded by small faculae.
10	2.00 p m	0	0	1	3	Good.	
11	11.50 a m	0	0	1	3	Fair.	Group on Meridian.
12	11.55 a m	0	0	1	2	Good.	
13	11.20 a m	0	0	1	2	Fair.	Spots small.
14	11.30 a m	0	0	0	0	Fair.	Apparently Clear Disc.
15	12.00 m	0	0	0	0	Poor.	Light clouds.
17	11.25 a m	0	0	0	0	Good.	Small faculae on E. limb. Groups faculae near SE.
18	12.10 p m	0	0	0	0	Poor.	Faculae SE. [and W. limb.
19	11.20 a m	0	0	0	0	Good.	Small faculae SE.
20	11.25 a m	0	0	0	0	Good.	Clear Disc.
21	12.00 m	0	0	0	0	Poor.	Haze.
22	11.25 a m	1	2	1	2	Good.	Group surrounded by faculae on E. limb.
23	1.40 p m	0	3	1	5	Good.	1 large spot. Large area faculae.
24	12.10 p m	0	2	1	7	Good.	1 large spot.
25	12.00 m	3	?	4	?	Bad.	Hazy. Single glimpse through clouds. Group N. Lat. 3 very large spots with umbra and penumbra.
26	12.00 m	0	?	4	19	Good.	Groups close together. Numerous small spots. Slight haze. 3 large spots unchanged.
27	11.45 a m	0	0	4	12	Fair.	Could not count all smaller spots.
28	11.50 a m	0	0	4	15	Good.	1 large spot with umbra and penumbra.
29	11.45 a m	0	0	4	11	Poor.	Large spot unchanged. Hazy. Could not count smaller spots.
30	2.45 p m	0	0	3	?	Poor.	Very hazy. Faculae E. limb. Group NE.

Cloudy on 2d, 6th, 7th, 8th, 16th.

DECEMBER, 1890.

Date.	Central Time.	No. of New		No. of Visible		Definition	Remarks.
		Groups.	Spots.	Groups.	Spots.		
3	11.45 a m	0	0	1	1	Fair.	Large spot on NW. limb disappearing by solar rotation.
6	12.00 m	0	0	0	0	Poor.	Hazy.
7	1.30 p m	0	0	0	0	Good.	Small faculae on NW. limb. Faint group faculae near E. and SW. limb.
8	12.10 p m	0	0	0	0	Good.	Apparently Clear Disc.
9	11.20 p m	0	0	0	0	Fair.	Apparently Clear Disc.
10	12.00 m	0	0	0	0	Poor.	
11	11.15 a m	0	0	0	0	Good.	Clear Disc.
12	11.25 a m	0	0	0	0	Fair.	Small faculae near E. limb.
14	2.20 p m	2	10	2	10	Good.	Larger group S. latitude on Meridian. Other group W. about ¼ across Disc.
15	11.40 a m	1	4	3	14	Poor.	Small faculae near SE. limb. Very hazy. Could not count all spots. New group E. of larger group.

DAVID E. HADDEN.

Solar Prominences for November.

DATE.	POSITION ANGLE.
1	80, 165, 250, 276, 316.
2	166, 245 to 268.
4	253, 260, 295.
5	150, 168, 255.
7	172, 251, 336.
16	144, 260.
20	88, 140, 262, 309.
21	50, 234.
22	50, 151, 255.
23	55, 150, 252, 270, 310.
27	150.
30	236, 327.

NOTE.—During latter half of month definition has been very bad.
Camden Observatory December 1st, 1890.

Astronomical Phenomena during the Year 1891.

The principal phenomena predicted for the year 1891 are four eclipses, two of the sun and two of the moon, a transit of Mercury over the sun's disk, and the disappearance and reappearance of Saturn's rings. Of these the last two will excite the most interest.

A total eclipse of the moon, May 23, will be invisible in the United States, but visible generally throughout the western part of the Pacific Ocean, Australia, Asia, Africa and Europe.

An annular eclipse of the sun, June 6, will be visible in the northern part of Siberia. It will be visible as a partial eclipse in the western part of the United States, in British America, Europe and Siberia.

A total eclipse of the moon, Nov. 15, will be visible throughout North and South America, Asia, Africa, Europe and the Atlantic Ocean. It will begin at $3^h\ 36^m$ and end at $9^h\ 03^m$ P. M. Central Time. We expect later to give a chart of the moon's path among the stars during this eclipse, and a list of the stars which will be occulted.

A partial eclipse of the sun December 1 will be visible only in the southern part of South America and the south polar region.

The Transit of Mercury across the sun's disk will take place on May 9, beginning at 5^h 55^m and ending at 10:53 P. M. central time. It will be partly visible in the United States and throughout the western part of North and South America and Asia. The whole transit will be visible in Japan, China, Eastern Siberia, Australia, and the Malaysian Islands. It is not likely that any expeditions will be sent out for the purpose of obtaining observations of this transit under favorable circumstances, for such observations would be of value only in determining the place of the planet. The solar parallax, for which such great pains have been taken in observing transits of Venus, has, by other means, been determined with much greater accuracy than could be attained from transits of Mercury. There are however, interesting questions as to the planet's appearance during transit, its atmosphere and motion. No one who has the opportunity to observe this transit should neglect to make all the use possible of it.

Professor G. W. Coakley, of the University of New York, has computed the times of the contacts for several of the observatories of the United States, data which will be found very useful to those wishing to observe the transit.

On Sept. 22 the earth will pass through the plane of Saturn's rings. The rings then, in telescopes of sufficient power to show them, will appear as a fine straight thread of light. From Sept. 22 to Oct. 30 the earth will be above the plane of the rings, while the sun will be below that plane, shining upon the south side of the rings. The rings then should entirely disappear, except the very fine thread of light which comes from the outer edges of Rings *A* and *B*. After Oct. 30 the sun will be on the north side of the plane of the rings, so that its light will illuminate the same side of the rings at which we look. Many interesting observations were made at the time of the disappearance of Saturn's rings in 1878 and, although the position of the planet will be very unfavorable, it is to be hoped that many of them will be repeated this year, and accurate data obtained for the solution of the problems connected with the rings. Saturn will be in conjunction with the sun on Sept. 12, so that at the time of the disappearance of the rings it will be very close to the sun and can be observed only very near the horizon.

We will give in our next number an abstract of a paper by Professor Trouvelot on his observations in 1877-78, with his suggestions as to the observations which should be made this year.

Transit of the Planet Mercury over the Sun's Disk, May 9, 1891.

At the Lick Observatory, Mt. Hamilton, Cal.,

The Exterior Ingress takes place,	11^h 54^m $17^s.99$	Greenwich Mean Time.
or,	3^h 54^m $17^s.99$	Pacific Standard Time.
The Exterior Egress takes place at	16^h 50^m $20^s.52$	Greenwich Mean Time.
or	8^h 50^m $20^s.52$	Pacific Standard Time.

At this last phase of the transit the sun will be below the horizon for alparts of the Pacific Coast, with the possible exception of some of the northern portions of Alaska. At places farther east the times of Egress will be still later, and hence have not been computed.

At Carleton College Observatory, Northfield, Minn.,
Exterior Ingress takes place at $11^h\ 54^m\ 26^s.68$ Greenwich Mean Time.
or $5^h\ 54^m\ 26^s.68$ Central Standard Time.

At Chicago, Ill.,
Exterior Ingress takes place at $11^h\ 54^m\ 19^s.73$ Greenwich Mean Time.
or $5^h\ 54^m\ 19^s.73$ Central Standard Time.

At New York City,
Exterior Ingress takes place at $11^h\ 54^m\ 25^s.81$ Greenwich Mean Time.
or $6^h\ 54^m\ 25^s.81$ Eastern Standard Time.

At the Naval Observatory, Washington, D. C.,
Exterior Ingress takes place at $11^h\ 54^m\ 18^s.64$ Greenwich Mean Time.
or $6^h\ 54^m\ 18^s.64$ Eastern Standard Time.

At Cambridge Observatory, Mass.,
Exterior Ingress takes place at $11^h\ 54^m\ 32^s.55$ Greenwich Mean Time.
or $6^h\ 54^m\ 32^s.55$ Eastern Standard Time.

GEORGE W. COAKLEY.

NEWS AND NOTES.

In sending names and addresses to the MESSENGER, correspondents are especially urged to write plainly, and in the case of renewals of subscriptions the address previously used should always be stated whether a change is desired or not. By so doing mistakes in the mailing lists will be prevented.

The prospects for Volume X of the MESSENGER for the year 1891 are certainly very bright. Never before have the books shown so long a list of renewals and new names in the month of December. The increase of the subscription price of the last year has had the opposite effect from that anticipated. Instead of a lessened number of subscribers the books show an actual and considerable increase. And a general and hearty support before unrealized has been given in various ways.

With such encouragement in our work, further improvement will be possible and is even now under contemplation. One new feature of which we have spoken before will have its beginning in our next number. Professor W. C. Winlock, Superintendent of the Bureau of International Exchanges, has furnished copy already for the Bibliography of Astronomy for a considerable part of the year 1890. This most useful addition to our annual record of the progress of Astronomy will hereafter appear regularly, and will follow the dates and events they record so closely as to be of the largest possible service to all interested in the various branches of Astronomy.

The reprint of Volume I of the MESSENGER will be undertaken as soon as the next publication of Carleton College Observatory is through the press. The second publication (though not so numbered) is a full set of tables for various reductions of observatory work, and this volume is now in the hands of the binder. The copy for the next publication is nearly all in

the printer's hands and it will be completed and distributed before the middle of February, 1891. The calls for full sets of the MESSENGER continue to come, and we now hope to fill all such orders during the month of March. The prices for the several volumes unbound are as follows: Volume I, $5.00 (scarce); II, III, IV, V, VI, VII, VIII, $2.00 each; IX, X and later ones each, $3.00. Prices for bound volumes on application.

The appearance of a new periodical devoted to Astronomy, titled *The Journal* of the British Astronomical Association, is a welcome visitor at our table. Its first number bears date October 1890, and has the familiar name of E. W. Maunder as editor. This number contains an account of the general meeting of the Association on October 24, the list of officers of the Council, rules of the Association, report of the provisional committee and its circulars, two excellent papers, one, on the rotation periods of the planets Mercury and Venus, by Miss A. M. Clerke; the other, on the chief nebular line, by E. W. Maunder. These are followed by book notices, correspondence, and 'notes' of general and current interest. This number contains 48 pages and clearly indicates a vigorous beginning for the new association and a purpose to maintain a strong journal in the interest of Astronomy. The membership of the Association has already reached 350. THE MESSENGER extends hearty congratulations.

Copley Medal to Professor Newcomb. The Copley Medal of the Royal Society, London, has been awarded to Professor Simon Newcomb, Superintendent of the American Ephemeris, Washington, D. C., for his contributions to gravitational astronomy. The medal was first given by the Society in 1753, to Dr. Benjamin Franklin. The following named persons, respectively, have received this honor during the last thirty years:

1860. R. W. Bunsen.
1861. L. Agassiz.
1862. T. Graham.
1863. A. Sedgwick.
1864. C. Darwin.
1865. M. Chasles.
1866. J. Plucker.
1867. K. E. von Baer.
1868. C. Wheatstone.
1869. H. V. Regnault.
1870. J. R. Joule.
1871. J. R. Mayer.
1872. F. Wöhler.
1873. H. L. F. Helmholtz.
1874. L. Pasteur.
1875. A. W. Hofmann.
1876. C. Bernard.
1877. J. D. Dana.
1878. J. B. Boussingault.
1879. R. J. E. Clausius.
1880. J. J. Sylvester.
1881. K. A. Wurtz.
1882. A. Cayley.
1883. Wm. Thompson.
1884. C. Ludwig.
1885. A. Kekule.
1886. F. E. Neumann.
1887. J. D. Hooker.
1888. T. H. Huxley.
1889. G. Salmon.
1890. S. Newcomb.

The mathematical medalists in the previous years have been; Waring, 1784; Ivory, 1814; Gauss, 1838; Sturm, 1841, and Chasles, Plucker, Sylvester, Cayley, Thompson and Salmon as indicated in the above table.

It also gives us pleasure to notice in the *Washington Star*, Nov. 29, that Professor Newcomb has also been recently remembered in a very handsome way by distinguished persons and institutions in foreign lands. The University of Tokio, Japan, has presented him with two fine, large

bronze vases, finished specimens of Japanese art, in recognition of his aid in selecting a suitable person to construct a photo-heliograph for the University.

A present from Russia by order of the Czar is also tendered to Professor Newcomb on account of esteemed services rendered in procuring, for the government, the great 30-inch telescope a few years ago mounted at Pulkowa. This gift is a large, jasper vase on a marble base. Such tokens of regard proffered from three different foreign lands, and that for incidental scientific services only, show well the rank of American science at the present time.

Observations of Venus near Inferior Conjunction in the first part of December. In answer to your request, I take pleasure in sending you my notes concerning the close conjunction of Venus with the sun in the first part of this month.

I had made preparations to observe the conjunction, but a spell of bad weather set in on the 1st of December and lasted until the 5th, thus completely blotting out the heavens during the important time. However, what few notes I did secure may be of interest.

November 29. The crescent is very thin. The southern horn extends farther than the northern. No trace of the dark part of Venus.

Dec. 1. The horns extend through about 270°. The southern cusp can be traced much farther than the other, and is much more slender.

Dec. 2. Cloudy.

Dec. 3. Cloudy.

Dec. 4. Cloudy.

Dec. 5. Sidereal $16\frac{1}{2}^h$. Nearly the entire circumference is visible; at least eight or nine-tenths of the ring of light is distinctly traceable. At times the circle appeared to be complete, but I do not think that it was nearly so. No markings of any kind were seen either in the crescent or on the dark body of Venus. The air was, as usual here in the day, very unsteady, and delicate details would have been lost. The body of the planet was of the same depth of shade as the sky and no contrast between the two was seen. The observations were made with the 12-inch equatorial and its finder ($3\frac{1}{4}$-in.) with magnifying powers of 50 ±, 80 and 150.

I regret exceedingly the unfortunate storm which blotted out the planet on the 2d, 3d and 4th of December, for, from the observations of the 5th, I feel certain the entire circumference would have been visible on the 4th.

Mt. Hamilton, Dec. 12, 1890. E. E. BARNARD.

Hough's Catalogue of 94 New Double Stars. In *A. N.* 2977 will be found the catalogue of 94 new double stars by G. W. Hough, Director of Dearborn Observatory, Evanston, Ill. This catalogue contains 48 pairs having a distance of less than 0″.5, a larger number of close doubles than we remember to have seen in any other similar publication.

Swift's Ninth Catalogue of New Nebulæ. Dr. Lewis Swift is still at work in finding new nebulæ. His ninth catalogue of 100 new nebulæ will be found in the *Astronomische Nachrichten* No. 3004. He is now well started on the tenth catalogue of these faint objects.

Spectroscopy at the Paris Observatory. M. Deslandres has charge of the spectroscopic section recently created at the Paris Observatory, and in a recent number of the *Comptes Rendus* an account is given of the instruments to be used with the great equatorial whose aperture is 1.20 meters. The difficulty of adjusting a star to the slit of the spectroscope for the purpose of photographing the spectrum seems to be nicely overcome. To do this M. Deslandres has arranged a total reflecting prism near the dark side so that the red end of the spectrum may be seen while the blue end is being photographed. In this way he has obtained many photographs of stellar spectra in juxtaposition with comparison spectra. To adjust the instrument for observing the spectrum of a star, a small mirror having a hole in the center, about the same diameter as the length of the slit, has been fixed in front of the slit at an inclination of 45°. The image of the star is thus reflected to the side of the instrument, and, after another reflection reaches a small telescope fixed at the spectroscope. The telescope, therefore, gives the image of a star, in the plane of the slit, and constitutes a veritable finder for use with the spectroscope.—*Nature*, Oct. 30, 1890.

A Jena Glass Visual Objective Used as a Photographic Lens. I have a Jena glass objective of two and one-tenth inches aperture and thirty-five inches focal length, made by Brashear for visual use, which gives very good photographic images. With one second exposure the image of Polaris is less than 0.002 inch in diameter; with ten seconds' exposure, between 0.003 and 0.004 inch. Equatorial stars of the 6th magnitude give trails less than 0.001 inch wide. With very slight magnifying the plates bear measuring to within five seconds of arc. J. A. PARKHURST.

Marengo, Ill.

Report of Yale University Observatory. The last report of the Observatory of Yale University for the year 1889-90 has just been received. It bears date of June 18; so its contents are rather old. It was then said that the measures of Victoria and Sappho, by the heliometer, were well kept up, and required only a final revision. It was then proposed to take again the observations on the parallaxes of the first magnitude stars in the northern hemisphere, with the intention of carrying out the work as first planned. Dr. Elkin thinks that the advantages of the heliometer for these bright stars are such as to make it well worth while to pursue the investigation without the fear of being immediately supplanted by the photographic method of observation, although he thinks the latter method will prove certainly superior for all but the very brightest stars.

Progress of Astronomy in 1887 and 1888. An account of the progress in astronomy for the years 1887 and 1888, as prepared by William C. Winlock, Superintendent of the Bureau of International Exchanges, Smithsonian Institution, Washington, D. C., has been received. It is a pamphlet of about 90 pages, and essentially the same in plan and form as its companions of 1885 and 1886. It is a very general, compact and useful *resume* of the astronomy of those two years.

XUM

Saturn and Its Rings is the title to Appendix II of Washington Observations of 1885. It contains a list of observations of Saturn from 1875 to June 1, 1889, by Professor Asaph Hall of the U. S. Naval Observatory, Washington, D. C. By this study Saturn's rotation time is found to be $10^h\ 14^m\ 23^s.8 \pm 2^s.30$. This value has been adopted by the latest and best text-books on astronomy. Professor Hall speaks of the anomalous curvature of the outline of the shadow of the ball on the rings in 1876, when the convexity of it appeared to be turned toward the planet, contrary to what one would expect from geometrical considerations. In 1878 something of this kind was seen at Washington after the reappearance of the ring. Professor Hall thinks that this appearance seen when the ring was very narrow, arose from the shortness of the outline, and a little bluntness in the ends of the shadow. This would not account for the reversed curvature of the shadow as observed by Aldro Jenks April 25, 1889, an account of which was published in No. 86 of THE MESSENGER. Professor Hall further says: "No notch has ever been seen in the outline of the shadow." In 1851 Otto Struve, of Pulkowa, thought that the dimension of Saturn's ring was undergoing a secular change, that in a short interval of about 100 years would bring its inner edge in contact with the planet. This theory has been adopted by Maxwell and Hirn in their mechanical investigations on the constitution of the ring. In comparing his own measures with those of Bradley in 1719 and those of later astronomers Professor Hall finds that there is apparently no change in the dimension of the Ring during 167 years.

Following these notes and the discussion of them, two full page plates of Saturn are found. They are weak and disappointing representations of what is known of the details of Saturn's surface.

The Orbit of 70 Ophiuchi. With reference to Mr. Mann's interesting article on binary stars in THE SIDEREAL MESSENGER for November 1890, I computed an orbit for 70 Ophiuchi in the year 1888, and my results were published in the Monthly Notices of the R. A. S. for March of that year. The elements I found were as follows:

$P = 87.84$ years	$\Omega = 120°\ 5'$ (1880.0)
$T = 1807.65$	$\lambda = 171°\ 45'$
$e = 0.4912$	$a = 4''.50$
$\gamma = 58°\ 28'$	

These elements, which do not differ much from Mr. Mann's, represent all the measures fairly well from 1802 to 1889. A diagram of the apparent orbit, drawn to scale, will be found in my "Scenery of the Heavens," p. 193, and also in *Knowledge* for August, 1890. I find, as Mr. Mann does, that the line of nodes nearly coincides with the projection of the major axis. My elements give the following ephemeris:

Date.	Position-Angle.	Distance.
1890.50	334°.08	2″.03
1891.50	325 .44	2 .13
1892.50	317 .54	2 .22
1893.50	310 .09	2 .28
1894.50	302 .92	2 .30
1895.49	295 .75	2 .27 periastron passage.

Ballysodare, Ireland, Nov. 27. 1890. J. E. GORE.

Time Service and the U. S. Naval Observatory. A person who well understands how things go on the inside of the United States Naval Observatory, has recently written us pretty fully concerning the status of the time question and the attitude of those whose judgment has been depended on in the late action of the Secretary of the Navy. The information, as unfavorable as it is for some, is doubtless true every word of it, for it is only a piece of what has been developed during the last year, and shown in the papers generally to the utter disgust of four-fifths of those interested in astronomy. The plan suggested by this friend from whom we have not heard before, is a good one, and there is more hope of its success in view of the marked changes in political power now in progress than possibly could have been expected under existing authority. The indications are not only a "stiff breeze from the northwest," but a ventilating blizzard from every point of the compass to give Washington a little healthful airing.

Annals of the Harvard College Observatory, Vol. XXIV. The discussion of the measurements made with the Meridian Photometer during the years 1882 to 1888 is found in Vol. XXIII of the Annals. The principal results obtained will be found in the present volume. The stars were mainly selected from the Durchmusterung and are brighter than 9.1 magnitude. A further collection of miscellaneous objects whose brightness is derived by photography is also given. The total number of measurements in the work is 1,067, and the separate objects observed are 20,982; four photometric settings were made on each object, and these repeated three or four times. Total number of settings 267,092. The aperture of the telescope used was four inches, and stars of the ninth magnitude were, of course, easily observed, and the measures of different nights are accordant, showing a deviation of not more than 0.11 of a magnitude. Professor E. C. Pickering himself made about two-thirds of the measurements and Mr. O. C. Wendell the remainder.

Vol. XXI, Pt. 2, of the Annals is also on hand. It contains the investigations of the New England Meteorological Society for the year 1889.

Vol. XXX, Pt. 1, of the Annals contains observations made at the Blue Hill Meteorological Observatory in the year 1889.

Still another interesting publication from the same source is the History of the Harvard College Observatory during the period 1840 to 1890. This was prepared by Daniel W. Baker and appears in neat pamphlet form as a reprint from the Boston *Evening Traveler*. It is fully illustrated.

The Cordoba Durchmusterung. No. 230 of the *Astronomical Journal*, Boston, Mass., contains an account of the work at Cordoba, by John W. Thome, Director of the National Observatory of the Argentine Confederation, on the Southern Durchmusterung. The results discussed in the article are drawn from work that has been going on for the last five years. It is perhaps generally known that Schönfeld's great work reached to $-22°$ in declination. Mr. Thome has extended this star survey to $-42°$ in declination, making more than a million of observations of the stars in this intervening belt of 20°, where such useful information is much needed.

Theory of Moon's Motion has again been under discussion of late by John N. Stockwell of Cleveland, Ohio, and G. W. Hill of Washington, D. C. The articles referred to will be found in the *Astronomical Journal*, Nos. 220, 226 and 231. Mr. Hill criticises Mr. Stockwell's method of computing the secular motion of the moon's perigee in two particulars; (1) he claims that the differential equation of the motion of the perigee should contain no instantaneous element; (2) that the eccentricity of the earth's orbit should be regarded as variable in developing the differential equations of the moon's motion. Mr. Stockwell admits that the first point of criticism is well taken, but the second he claims is not good, although such authorities as Professor Adams and Delaunay have previously reached the same conclusions by different methods as that supported by Mr. Hill. The weight of authority is certainly against Mr. Stockwell, yet we shall look with interest for the results of his further study of this particular phase of this intricate problem.

Photographic Notes. The great importance now attached to the photographic method in astronomical research is markedly shown in the proceedings of the meeting of the Royal Astronomical Society as reported in the December Observatory. Mr. McLean's paper on High Sun and Low Sun Spectra was accompanied by a series of parallel photographs. This paper gives the ortho-chromatic method for obtaining such pictures. Mr. Higgs presented photographs of the A line in the solar spectrum. Mr. Russell's paper was on celestial photographs taken at the Sydney Observatory. Pictures taken by Professor Pritchard with his photographic charting telescope were received by the society. In regard to this instrument the following statement is made: "One of the tests adopted was to expose a plate to the sky for three minutes. Professor Pritchard then stopped the clock and removed the plate; afterwards he replaced the plate, brought the guiding star to the cross-wires, and made a second exposure. The two images coincided perfectly, and there is nothing to show that two exposures were given. Professor Pritchard also speaks in the highest terms of the reticule, and of his apparatus for measuring the size of star discs." Attention was also called to the photographic research made at the Lick Observatory by Professor Holden for the determination of the parallaxes of stars. Mr. Fowler stated that a photographic study of stellar spectra had been commenced at South Kensington under the direction of Professor Lockyer, and that one of the first results obtained was the discovery that α Lyrae is a binary star of the β Aurigae type. The method by which this discovery was made is described in the same paper.

Oscillation of the Earth's Axis. The *London Mail* for Nov. 26, 1890, has a brief article to the effect that Professor Alfred Kirchoff of Halle, has published a paper in the *Saale Zeitung*, on the great interest that scientific men looked forward to the autumn meeting of the International Conference on Degree Measurement, which was lately held at Freiburg. It had been reported that a series of simultaneous observations carried on at Berlin, Strasburg and Prague went to show that a decrease in latitude was in progress apparently in middle Europe, and further reports from other observatories showed that a similar phenomenon had been noted in other

places in Europe. This seemed to imply that a change was going on, in the direction of the earth's axis, amounting to a decrease of latitude at the end of the six months' period from Aug. 1889, to Feb. 1890, of one-half of a second of arc. But it was reported to the conference that the Berlin observations for the half year ending last August showed an increase of latitude amounting to two-fifths of a second. The question raised then is: Are there fluctuations of the earth's axis within the ball that will account for the changes of latitude observed wholly or in part? Or must astronomers find the explanation in other causes? Some American observatories will take part in the study of this important question soon, and simultaneous observations in the Prime Vertical will be taken by different observatories on or near the same parallel of latitude, but having as great a difference of longitude as six hours.

Dr. J. G. Galle, Director of the Observatory at Breslau, has recently kindly favored the Observatory Library of Carleton College with a number of publications prepared at Breslau since 1875.

BOOK NOTICE.

The Meteoric Hypothesis: A Statement of the results of a Spectroscopic Inquiry into the Origin of Cosmical Systems. By J. Norman Lockyer, F. R. S. Messrs. Macmillan & Co., London and New York. pp. 560. Price $5.25.

This volume is probably the most valuable one that has come from the ready pen of Mr. Lockyer. The object of it is to bring together and coördinate the observations that have been made up to the present time, on the spectra of the various orders of cosmical bodies in connection with laboratory work since 1868, and naturally follows the researches made by Mr. Lockyer relating to the origin of many solar phenomena as dependent on the fall of meteoric masses on the sun's surface. His investigations in this direction were published in 1887 in a book called *The Chemistry of the Sun*. In this volume the claim is made that the photographic study of nebular spectra has raised, so far, no new point of theoretical importance, and so it has been thought best not to delay its publication for detailed answer to objections that do not refer to the new hypothesis as a whole, but only touch it incidentally, or in minor detail. The author welcomes thorough and competent criticism and believes his hypothesis will be improved by all such thorough tests. As much is being said and will be said in THE MESSENGER about this new theory we will now give only a brief outline of the book. It is divided into nine parts. Part I has to do with the fall and nature of meteorites (1) a general record, the physical characteristics and the chemistry of these bodies.

Part II deals with the spectroscopy of meteorites by studying the spectra of metals found in them and of gases occluded in them.

Part III treats of meteorites in the air; the identity of origin of luminous meteors and falling stars with meteorites; the Aurora a phenomenon produced by the dust of meteors and falling stars, and the traces of meteoric dust in deep oceans.

Part IV is upon meteorites in the solar system, those which travel around the sun; demonstration of the cosmical hypothesis; these meteor swarms on comets; what the appearances of comets are when near and far from the sun, and the forces which produce the various forms of cometary swarms. The spectroscopy of comets and the origin of cometary phenomena.

Part V presents meteors in space, treating of the nebulae and of the stars.

Part VI gives the proposed new grouping of cosmical bodies in seven classes.

Part VII is on the origin of binary and multiple systems.

Part VIII, on the variability of light and color of cosmical bodies; and

Part IX, the general conclusions, followed by appendices and an index.

Books Received.

Upward Steps of Seventy Years, by Giles B. Stebbins. Publishers, United States' Book Company, New York, 142 and 150 Worth St.

Cosmical Evolution. A New Theory, by Evan McLennan. Publishers, Messrs. Donohue, Henneberry & Co., Chicago.

An Introduction to Logic, Second Edition. By W. H. S. Monck, F. R. A. S. Publishers, Messrs. Hodges, Figgis & Co., Grafton St., Dublin, and Messrs. Longmans, Green & Co., Paternoster St., London.

The Elements of Solid Geometry by R. Baldwin Haywood, M. A., F. R. S. Publishers, Messrs. Macmillan & Co., London and New York. 1890.

Progress of Meteoric Astronomy in America is the title of a full and exhaustive paper read by Professor J. R. Eastman of Washington, D. C., before the Philosophical Society of Washington.

Spectroscopic Measures of Stellar Motions. Professor C. A. Young published in the December No. of *Popular Science News* (Boston) a very timely statement of late results from the Spectroscope in the determination of stellar motions.

Errata.—Line 4, page 32, for *interesting* read *inverting*. Line 6, page 32, for *elangation* read *elongation*. Line 8, page 18, for *stangely* read *strangely*. Line 19, page 23, for *and* read *und*.

TELESCOPES FOR SALE.

A TELESCOPE, 4 5-16-inches, clear aperture, brass tube tripod, diagonal and a number of eye-pieces. Address S. L. B., 25 Montrose St., Roxbury Dist., Boston, Mass.

A CLARKE TELESCOPE, 4-inch aperture, five feet focus, in brass, equatorially mounted, with circles, finder, heavy iron stand, 4 eye-pieces and diagonal. Cost $300. Price $225. N. M. M., 1823 Cass St., Omaha, Nebr.

A BYRNE TELESCOPE, 4-inch aperture, said to be in first class condition. Owner wishes to sell to get a larger one. Address J. C. M., Red Wing, Minnesota.

A TELESCOPE for sale, 5⅝-inches aperture; 91 inches focal length, said to be an instrument of excellent definition. Address H. O. F., Astronomical Association, Bloomington, Ills.

A BARDOU TELESCOPE of 3.35 clear aperture, iron pillar mounting, 4 positive and 2 negative eye-pieces, bright and dark illumination for wires. Both circles read to minutes with clock work. W. E. W., Architect's Office, Washington, D. C.

TWO REFLECTING TELESCOPES for sale. Description of them not given. Address G. S. J., 1623 Montgomery St., Philadelphia, Penn.

A 4½-INCH CLACEY GLASS. Focal length 48 inches. Rack and pinion. Five eye-pieces. Said to be first class. Price $285. Address J. J., 16 Chester St., Boston, Mass.

A 2½-INCH ACHROMATIC Telescope equatorially mounted will be sold to give place to a larger instrument. Address L. F. C., 1332 Huron St., Toledo, Ohio.

THREE TELESCOPES for sale over and under 4 inches aperture. Owner wants a larger instrument. J. A. D., Canton, Ohio.

A BYRNE TELESCOPE, 5¼ inches aperture with full set of accessories. Apparently a bargain. Address H. H., 14 & 16 Astor Place, New York.

Publishers' Notices.

NORTH AMERICAN REVIEW

A good instance of the enterprise of THE NORTH AMERICAN REVIEW is that the January number will contain articles on "The Future of the Indian Question," by General Nelson A. Miles: on "Ireland in the Light of History," by W. E. H. Lecky; and on "The Restriction of Immigration," by the Hon. Henry Cabot Lodge. Probably no three subjects are so prominent in the minds of Americans at the present moment as these; and these subjects could not have been assigned to abler contributors than General Miles, Mr. Lecky and Mr. Lodge.

LITTELL'S LIVING AGE.

In 1891 THE LIVING AGE enters upon its forty-fourth year. It has met with constant commendation and success.

The Foremost Living Writers.

The ablest and most cultivated intellects, in every department of Literature, Science, Politics, and Art, find expression in the Periodical Literature of Europe, and especially of Great Britain.

The Living Age, forming four large volumes a year, furnishes from the great and generally inaccessible mass of this literature the only compilation that, while within the reach of all, is satisfactory in the COMPLETENESS with which it embraces whatever is of immediate interest, or of solid, permanent value.

It is therefore indispensable to every one who wishes to keep pace with the events or intellectual progress of the time, or to cultivate in himself or his family general intelligence and literary taste.

RUDYARD KIPLING contributes the complete novel, "The Light that Failed," to the January number of LIPPINCOTT'S MAGAZINE. Kipling is attracting more attention at present than any other living writer. His force and originality have taken the world by storm. "The Light that Failed" is this brilliant author's first novel and fully justifies the expectations he has raised by his remarkable short stories. It is the story of an artist's life and love, and Kipling shows that he fully understands an artist's outlook upon life, and his hopes, expectations, and fears. It is his comprehension of the inner and outer life of men, and his ability to portray both, that is the secret of Kipling's power. In him what is called realism and idealism are blended. The love-story running through this powerful novel is a striking and original one, and altogether the story is one that no one should fail to read.

THE SCIENTIFIC AMERICAN, published by the great patent agency firm of Munn & Co., New York, is the most practically useful publication of its kind in the country. Indeed, it occupies a field distinctively its own. Not alone for the machinist, manufacturer, or scientist, but it is a journal for popular perusal and study. It is the standard authority on scientific and mechanical subjects. It is placed at a very low rate of subscription, $3 per annum, which places it within the reach of all. Subscriptions will be received at the office of this paper.

Electric Break Circuit
CHRONOMETERS.

WM. BOND & SON,
134 State Street,
Boston, Mass.

We were the original makers of these Chronometers in the United States and our System is still the best in use.

SEND FOR CIRCULAR.

Electro Nervine.

Cures Permanently all Diseases of the Nervous System, either Acute or Chronic in either sex. It **RESTORES** Impaired or Lost **POWER.** Checks all forms of Waste or Drain; Makes Strong the Weak. Full package, $1; Six for $5, Trial package 12c. (with book), sent securely sealed on receipt of price. Address DR. G. F. ADDAM, No. 3701 Cottage Grove Ave., Chicago, Ill.

Quinine Overcoats.

Few people have any idea of the amount of quinine that is consumed in a period of time, or of that sold by a single dealer in the drug. Extravagant stories have been told by individuals as to the amount of the alcholoid which they have consumed, and if it had not been quantity sufficient to have put them in a wooden overcoat it would probably, converted into cash, provide a comfortable top coat for winter wear. This time of year overcoats are out of season, and the question uppermost is how to keep cool and where. Rest and recreation come in that line. Thoughts of this kind should lead one to inquire of any agent of the Minneapolis and St. Louis Railway as to summer rates to tourists points in all parts of the country, or for a short fishing excursion. Any special information will be cheerfully furnished upon application to C. M. Pratt, G. T. & P. A., Minneapolis.

WANTED—A second-hand Transit Circle or Transit suitable for a working Observatory. Must be in good condition and considerably below first cost. Address W. R. HOAG.
1516 Seventh St. South-East, Minneapolis, Minn.

FOR SALE—Achromatic Telescope, equatorially mounted on long folding tripod, without circles or clock movement. Objective 3 inches clear aperture, 40 inches solar focus. Four astronomical eye-pieces with the following powers, linear, 40, 80, 160, and 250. Show distinctly the companions of Beta Orionis and Alpha Lyræ. Main tubes are brass polished and lacquered, sliding tubes nickel-plated, rack and pinion for adjusting focus. All parts in good condition. Price $70 cash. Purchaser must pay express charges. WILL T. FINCH, Whitehall, N. Y.

TELESCOPE FOR SALE CHEAP. 8-inch Objective, 9⅓ feet focus, 6 eye-pieces, 2 inches to 1-16 inch. Also a Diagonal by the Elder-Fitz. Optical parts perfect, tube, etc., need burnishing. Inquire of
WM. F. PURDY, Tarrytown, New York.

GONIG WEST?

Minnesota, North Dakota, Montana, Idaho, Oregon, Washington, California, British Columbia and Alaska,

Are all reached to the best advantage via the

NORTHERN ◎ PACIFIC
—RAILROAD—

—THE—

"Yellowstone Park and Dining Car Route."

Pullman Palace Sleeping Cars,
Elegant Dining Cars,
Furnished Tourist Sleeping Cars,
and Free Colonist Sleepers.

No other line runs Pullman Palace Sleeping Cars to Fergus Falls, Fargo, Crookston Grand Forks, Grafton, Winnipeg and Helena.

Through Vestibuled Train Service Daily

To all principal Montana and Pacific Coast Points

Via The Northern Pacific Railroad

THE SHORT LINE TO

Helena and Butte, Montana,
Spokane Falls, Washington,
and Portland, Oregon,
and the only all rail line to Tacoma and Seattle

THE FAVORITE ROUTE FOR CALIFORNIA TOURISTS.

For full information concerning rates, time, etc., call on or address your nearest ticket agent, any traveling passenger agent of the Company, or

CHAS. S. FEE,
General Passenger and Ticket Agent,
ST. PAUL MINN.

A Great Railway.

The Chicago Millwaukee & St. Paul Railway Company now operates over sixty-one hundred miles of thoroughly equipped road in Illinois, Wisconsin, Northern Michigan, Minnesota, Iowa, Missouri, South and North Dakota. Each recurring year its lines are extended in all directions to meet the necessities of the rapidly populating sections of country west, northwest, and southwest, of Chicago, and to furnish a market for the products of the greatest agricultural and stock raising districts in the world. In Illinois it operates 317 miles of track; in Wisconsin 1,636 miles; in Northern Michi- 96 miles; in Iowa 1,551 miles; in Minnesota 1,115 miles, in South Dakota 1,092 miles; in North Dakota 118 miles; in Missouri 140 miles, and the end is not yet. It has terminals in such large cities as Chicago, Milwaukee, La Crosse, St. Paul, Minneapolis, Fargo, Sioux City, Council Bluffs, Omaha, and Kansas City and St. Joseph, Mo., and along its lines are hundreds of large and small thriving cities, towns and villages. Manufacturing interests are cultivated, and all branches of trade find encouragement. The Railway Company has a just appreciation of the value of its patrons, and its magnificent earnings are the result of the good business tact which characterizes the management of its affairs.

The popularity of the line is attested by the fact that notwithstanding the strongest kind of competition of old and new lines, the Chicago, Milwaukee & St. Paul Railway continues to carry the greater proportion of all the business between Chicago, Milwaukee, St. Paul and Minneapolis. It is the best patronized route between Chicago, Council Bluffs and Omaha to and from all points in Wisconsin, Minnesota, Dakota and Iowa, and its Kansas City and St. Joseph line has taken equal rank with the older lines leading to and from the Southwest.

On all its through lines of travel the Chicago, Milwaukee & St. Paul Railway runs the most perfectly equipped trains of Sleeping, Parlor and Dining Cars and Coaches. The through trains on all its lines are systematically heated by steam. No effort is spared to furnish the best accommodations for the least money, and, in addition, patrons of the road are sure of courteous treatment from its employes.

Minnepolis & St. Louis

RAILWAY

AND THE FAMOUS

"Albert Lea Route."

TWO THROUGH TRAINS DAILY

FROM ST. PAUL AND MINNEAPOLIS TO

Chicago, St. Louis,

—AND—

Kansas City.

WITHOUT CHANGE, CONNECTING WITH THE FAST TRAINS OF ALL LINES FOR THE

East, Southeast, South, Southwest, and Pacific Coast Points.

SHORT AND DIRECT LINE TO

DES MOINES, IOWA,

—AND—

WATERTOWN, DAKOTA.

☞ Close connections made with all trains of the Great Northern; Northern Pacific; St. Paul & Duluth; Minneapolis, St. Paul & Sault St. Marie Railways from and to all points

NORTH AND NORTHWEST.

Comfortable Day Coaches,
Magnificent Pullman Sleeping Cars,
Horton Reclining Chair Cars,

—AND—

PALACE DINING CARS.

☞ 150 LBS. OF BAGGAGE CHECKED FREE. Fare always as Low as the Lowest! For Time Tables, Through Tickets, etc., call upon the nearest Ticket Agent, or write to C. M. PRATT,
Act'g Gen'l Tkt. & Pass. Agt., Minneapolis, Minn.

The H. R. Spencer Optical Co.,

CLEVELAND, OHIO,

SUCCESSORS TO H. R. SPENCER & CO., OF GENEVA, N. Y.,

—MANUFACTURERS OF—

Astronomical * Instruments

AND MICROSCOPE OBJECTIVES.

Telescope Object Glasses of any desired focal Length —Short Focus Glasses a Specialty.

Our New Formula Short Focus Astronomical and Terrestrial Telescopes embody many optical advantages besides the mechanical advantages of increased stability in their mounting and adaptability of large instruments to small observatories.

We make a specialty of small telescopes, of a very superior quality, for Astronomical and terrestrial purposes.

Estimates for object glasses, mounting, steel domes, and complete observatory outfits furnished on application.

Price list free.

THE H. R. SPENCER OPTICAL CO.,

21–29 SENECA STREET, CLEVELAND, O.

ASTRONOMICAL

TELESCOPES,

EQUATORIAL MOUNTINGS,

With and Without Circles.

DRIVING CLOCKS,
ACHROMATIC OBJECTIVES IN CELLS,
NEGATIVE AND POSITIVE EYE-PIECES,
DIAGONAL PRISMS.
HELIOSCOPES, SPECTROSCOPES,
CHRONOGRAPHS,
TRANSIT INSTRUMENTS.

PHILADELPHIA:

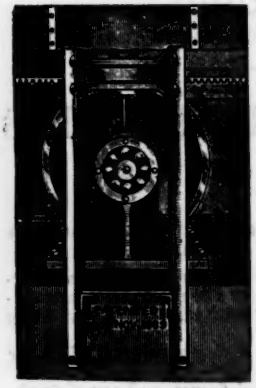
JAMES W. QUEEN & CO.,

No. 924 Chestnut Street.

SEND FOR CATALOGUE.

ASTRONOMICAL DOMES

BUILT ON THE HOUGH SYSTEM



Possess the following advantages over all others:

Minimum weight of rotating parts.

Ease of rotation and lateral stability attained by the use of adjustable stationary anti-friction wheels.

An opening continuous from horizon to zenith.

A shutter that closes weather-tight, will not bind, and can be quickly and easily operated.

Simplicity of construction, durability and cheapness.

The anti-friction wheels and shutter can be applied to existing domes with slight alterations and small expense.

A Dome built on the new method may be seen at the Dearborn Observatory, Northwestern University, Evanston, Ills.

For further particulars and estimates of cost address,

WM. SCHERZER, C. E.

509 Home Insurance Building, Chicago., Ill.

CARLETON COLLEGE,

Northfield, Minnesota.

Full Preparatory and Collegiate Departments.
English, Scientific, Literary and Musical Courses.
All Departments open to Students of Either Sex.
Expenses Very Low.

CALENDAR FOR 1890-91.

Examinations to enter the English Academy or Preparatory Department, the first afternoon of each term.

Examinations to enter the Collegiate Department, June 5th and 6th, and September 8th, 1891.

Winter Term begins Tuesday, January 6th, and ends March 18th, 1891.
Term Examinations, March 17th and 18th, 1891.
Spring Term begins Tuesday, March 24th, and ends June 11th, 1891.
Term Examinations, June 8th and 9th, 1891.
Anniversary Exercises, June 6th to 11th, 1891.
Wednesday, September 9th, 1891, Fall Term begins.

XUM